THE FOODS OF INSECTIVOROUS BIRDS AT KOWHAI BUSH, KAIKOURA.

A thesis

submitted in partial fulfilment

of the requirements for the

Degree

of

Master of Science in Zoology

by

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February 1989

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ACKNOWLEDGEMENTS

Special thanks must go to my wife, Pip, who has been an encouragement and helper in many ways as well as suffering many long absences.

My supervisor Ian McLean has always been supportive and his advice has been invaluable. He also takes the credit for inventing the caging technique.

Thanks go to Sue Mackle for permission to work on her land.

Department of Conservation provided a grant-in-aid for travel.

The Royal Forest and Bird Protection society generously provided from the Stocker Scholarship for video equipment and materials.

I thank the people who have helped in the field, at the Edward Percival Field Station, Zoology Department, and in many other ways; Jack van Berkel and his staff at Kaikoura, for many favours and kindnesses while at Kaikoura; Helen Rogers for looking after me so well; Dave Greenwoood, for his advice and help with video; Ian McLean, Shelley Dean, Sharon Faegly, and numerous helpers in the field; Mick Clout and other staff at the DSIR in Nelson for printer use and discussion; Peter Johns for the initial insect identifications, Brian Patrick for help with the moth identifications, Simon Pollard for help with the spiders; Steve Phillipson for discussion and help with statistics; The Akaroa Mail for type setting and help with diagrams; Mr Jansen for kindly binding the finished product. Lastly, but by no mean least, thanks go to the birds in our study area for putting up with my poking and prying, especially the grey warblers.

ABSTRACT

This study was designed to test a new method for researching the foods of passerine birds. The study site was located at Kowhai Bush, near Kaikoura, and consisted of successional Kanuka forest with little undergrowth. A grid system was used and most native birds were colour banded for the study. Chicks of five species of passerine and one species of cuckoo were removed from nests before fledging age, and placed in specially constructed artificial nest cages. Parents accepted cages readily and fed the chicks through the bars. Food items dropped in the nest and not retrieved by the adults were counted, weighed and identified. A video-camera was used to record the number and length of feeding visits parent birds made to nests. An estimate of the total daily food requirement was made.

Caging caused feeding rate and duration to increase, but chick weights were not significantly different to chicks in natural nests. Survival of chicks in cages was better than survival of naturally reared chicks for three species.

Applications of the caging technique include protecting chicks from predators, preventing chicks from leaving the nest before fledging, investigating food fed to chicks, developmental studies, and moving chicks to locations more convenient for research. The technique should be particularly useful in conservation biology.

Analysis of food items showed that some resource partitioning occurred between bird species. It was concluded that dropped items were representative of a nestlings diet. The use of caging as a non-destructive method of collecting feeding data was compared to the analysis of stomach contents and faeces. The results of the dietary aspect of this study have applications for wildlife management.

Over an entire breeding season grey warblers and fantails were followed within the gridded study area. Home range boundaries and areas were derived from field sightings of marked birds relative to the grid. Nest locations were plotted, and the outcomes of each nest were recorded up to the time of fledging. The implications of male song in warbler territory formation, size and defence are discussed as well as the female warblers role in nest positioning.

INTRODUCTION

The study of the foods in insectivorous birds has always posed a problem. Many methods are damaging to the bird being studied, meaning that for species that are rare or endangered, little food research has been undertaken. It is in these rarer species that a knowledge of the food requirements is most needed. This project was aimed at using a new technique for analysing the diets of small insectivorous birds. The technique is non-destructive and possesses other advantages which make it potentially suitable for endangered species research.

This thesis has been structured in three parts;

(i) Part one is a modified version of a paper in press for Journal of Wildlife Management. It describes the caging technique in detail and its effects on the birds studied. Applications of the technique, in particular for food research are discussed.

(ii) Part two details the the diets of rifleman, grey warbler, shining cuckoo and fantail chicks prior to fledging. The daily food requirements of chicks are described and discussed in relation to the management of endangered species.

(iii) The third section looks at the breeding success of fantails and grey warblers in one season. The effects of territory size, population density and nest location on breeding are discussed.

PART 1 "CAGING" AS AN ALTERNATIVE TECHNIQUE FOR STUDIES OF WILD PASSERINE BIRDS

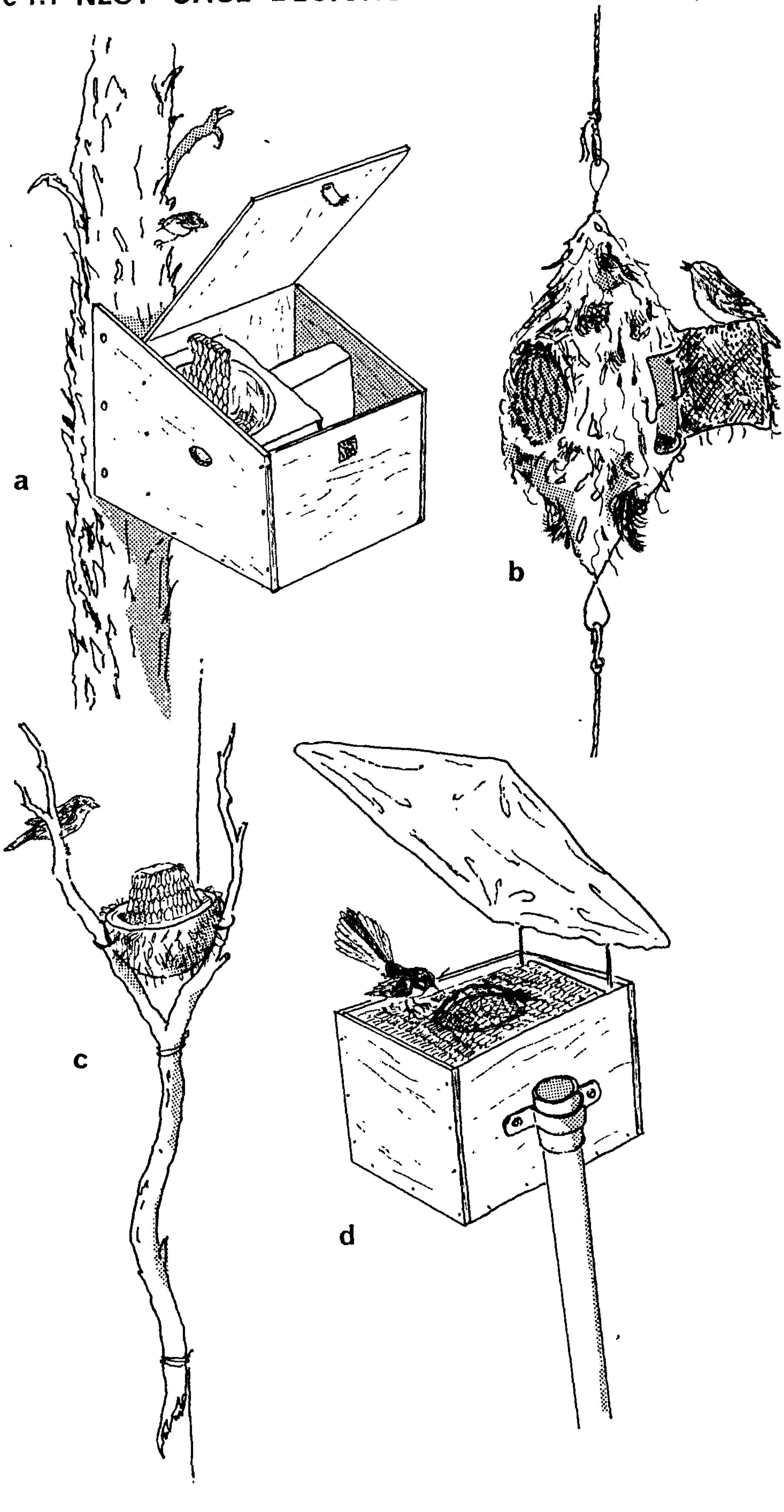
INTRODUCTION

Four problems often arise in studies of nestling birds in the wild: i) nest access (nests are often among spindly branches or at the tops of trees), ii) predation (sometimes induced by the activities of researchers), iii) abandonment by parents due to experimental interference; and iv) early fledging by chicks that refuse to remain in the nest when returned after handling. Chicks often react to handling and disturbance by calling. This attracts the parents and causes avoidable stress to the birds and researcher.

Having experienced the problems above, a technique was developed that may go some way towards solving them. Artificially constructed nest cages were developed and tested on five passerine species and one cuckoo species. The six species show a variety of nesting habits including open cup, pendulous and cavity nesting. The cuckoo is parasitic.

One of the advantages of the caging technique for feeding studies is that a proportion of the food items brought to the nestlings by the adult birds are dropped. Many different methods have been used to estimate the diets of birds, and of the non-invasive methods, faecal analysis has been the main one. Caging as a technique has the ability to provide extremely accurate food species identifications with little effect on the caged chicks. A simple video system can be used in conjunction with the cages for added accuracy. This study was designed as a test of the caging technique for studying food and development of passerine birds.

Figure 1.1 NEST CAGE DESIGNS



METHODS

Young birds close to fledging age were removed from the nest and placed in an artificial nest enclosed by a cage. The grill size was large enough for food to be passed through by parents, but small enough to ensure that heads of either parents or chicks could not be caught. Grill size and shape were adjusted by stretching chicken-wire mesh.

The wire barrier was positioned such that when chicks were begging, their bills just reached the cage bars. Expanded polystyrene was used for creating the "nest" within the cage. The "nest" bowl was then lined with absorbent paper towels. This lining was replaced daily.

Chicks of Rifleman (Acanthisitta chloris), fantail (Rhipidura f. fuliginosa), grey warbler (Gerygone igata), shining cuckoo (Chalcites l. lucidus), and chaffinch (Fringilla coelebs) were all successfully caged. The one caged brown creeper (Mohoua novaeseelandiae) nest was unsuccessful.

All manipulations were carried out at Kowhai Bush, near Kaikoura (42°23'S; 173°37'E) during the 1986/87, 1987/88 and 1988/89 seasons.

The nest cage structure depended on the species being manipulated (Figure 1.1). Rifleman use artificial nest-boxes at Kowhai Bush; cages consisted of an expanded polystyrene nest chamber inside the box with a removable wire grill placed inside the entrance hole (Fig 1.1a). Grey warblers build an enclosed pendulous nest; caging involved forming a pendulous shaped nest from wire mesh which was camouflaged with old warbler nests glued to the outside using silicone sealant (Fig 1.1b). The parents fed through a barred opening in the front while a door in the back of the nest allowed chicks to be removed. Shining cuckoos parasitize grey warblers and cuckoo chicks were also caged in artificial warbler nests. Fantails build open cup nests; caging was achieved using an old rifleman nest box with the top removed. Access was through a removable wire grill on the top (Fig 1.1d). The entire nest structure was placed on a plastic pole to prevent mammalian predators from climbing to the nest. One chaffinch nest was caged for two days as a test of the suitability of caging for species other than native arboreal insectivorous birds. A camouflaged cup type nest was constructed using the base of a plastic bottle attached to a forked branch (Fig 1.1c). Nests were protected from rain by plastic shelters where necessary.

Comparisons between caged nests and uncaged controls were made for all species (except chaffinch and brown creeper), assessing chick mortality, weight, feeding frequency and duration. A proportion of nests in 1987/88 and 1988/89 seasons were designated as controls when chicks attained the age at which they would be caged; chick mortality was measured from this time. In 1986/87, as most nests found were caged, no control nests were monitored.

Chicks were weighed every day as nest linings were replaced. Chicks were placed in a soft cotton bag and weighed using a "Pesola" spring balance of 30g capacity. Caged weights were compared with published data to see if caging had an effect on chick development (Fig 1.2).

A sample of nests were monitored during daylight hours using a video camera/recorder (Hitachi VM-500E), with attached character generator (Hitachi VM-CG20E) including a stopwatch function. The camera was set up in the field to record all activity at the nest for up to 12 hours a day, being recorded onto four tapes. The video data provided two main checks on the effect of the caging technique. Firstly, the duration time for each feeding visit was noted for both caged and uncaged nests, and secondly the number of feeding visits made to the nest in the day. Full three hour periods were not always possible due to equipment failure (batteries), by choosing the first 25 visits, more nests could be included in the analysis.

RESULTS

A total of 104 chicks from 40 nests were caged for 173 days (464 chick-days) during the study (Table 1.1 and Appendix 1). In 5 nests all chicks died. For only 3 of the caged nests studied did the deaths appear to have been caused directly by caging. The other deaths appeared to be natural consequences of climatic conditions or were attributed to attacks by predators.

Nestling mortality

Mortality in caged rifleman nests was 4.25% (Table 1.1). In 1987/88 and 1988/89 seasons, when control nests were monitored, there was no mortality in either caged or control nests. In comparison, two out of three natural nests (not in nest boxes) found within the study area were destroyed by predators. All chicks in 13 non-boxed nests found by Sherley (1985) in Kowhai Bush, suffered predation. Thus nest boxes protected chicks from predators, and caging within nest boxes has no apparent influence on mortality.

Mortality in caged fantail nests was 52.38% (Table 1.1). In 1987/88 and 1988/89, all chicks died in 2 of 7 caged nests, whereas only 4 chicks died in 5 uncaged nests. Parents were only once reluctant to feed caged chicks and on that occasion other fledglings (from a previous nest) were still being fed. The two nestlings were well below normal body weight for chicks of that age (nest F17).

Mortality in caged grey warbler nests was 15.62% (Table 1.1). In 1987/88, mortality in caged nests was 13.3% (2 of 15 chicks in 6 nests), whereas mortality (including mortality due to predation) of uncaged controls 33.3% (3 of 9 chicks in 5 nests). Both shining cuckoo chicks which were caged survived to fledging (Table 1.1), whereas one of the controls was preyed upon. Although some deaths occurred in caged warbler nests, caging did not increase mortality.

Table 1.1 Sample sizes and mortality for chicks of six species of bird reared in artificial nests ("cages") by the natural parents at Kaikoura New Zealand.

Species	# nests	# chicks	Mortality	Days Caged	Chick-days Caged
rifleman	18	47	2	106	285
fantail	7	21	11	23	76
grey warbler	11	32	5	33	92
brown creeper	1	1	1	<1	<1
shining cuckoo	2	2	0	9	9
chaffinch	1	1	0	2	2
total	40	104	19	173	464

Cages are known to have prevented predators from consuming chicks on 2 occasions: 2 warbler nests were attacked by avian predators. Holes stabbed through the plastic rain cover of one nest appeared to have been made by a magpie (Gymnorhina hypoleuca). Three of the 4 chicks died within 24 hours of this attack, 2 having been blinded; the fourth fourth

Figure 1.2 **RIFLEMAN CHICK WEIGHTS**

CAGED AND UNCAGED

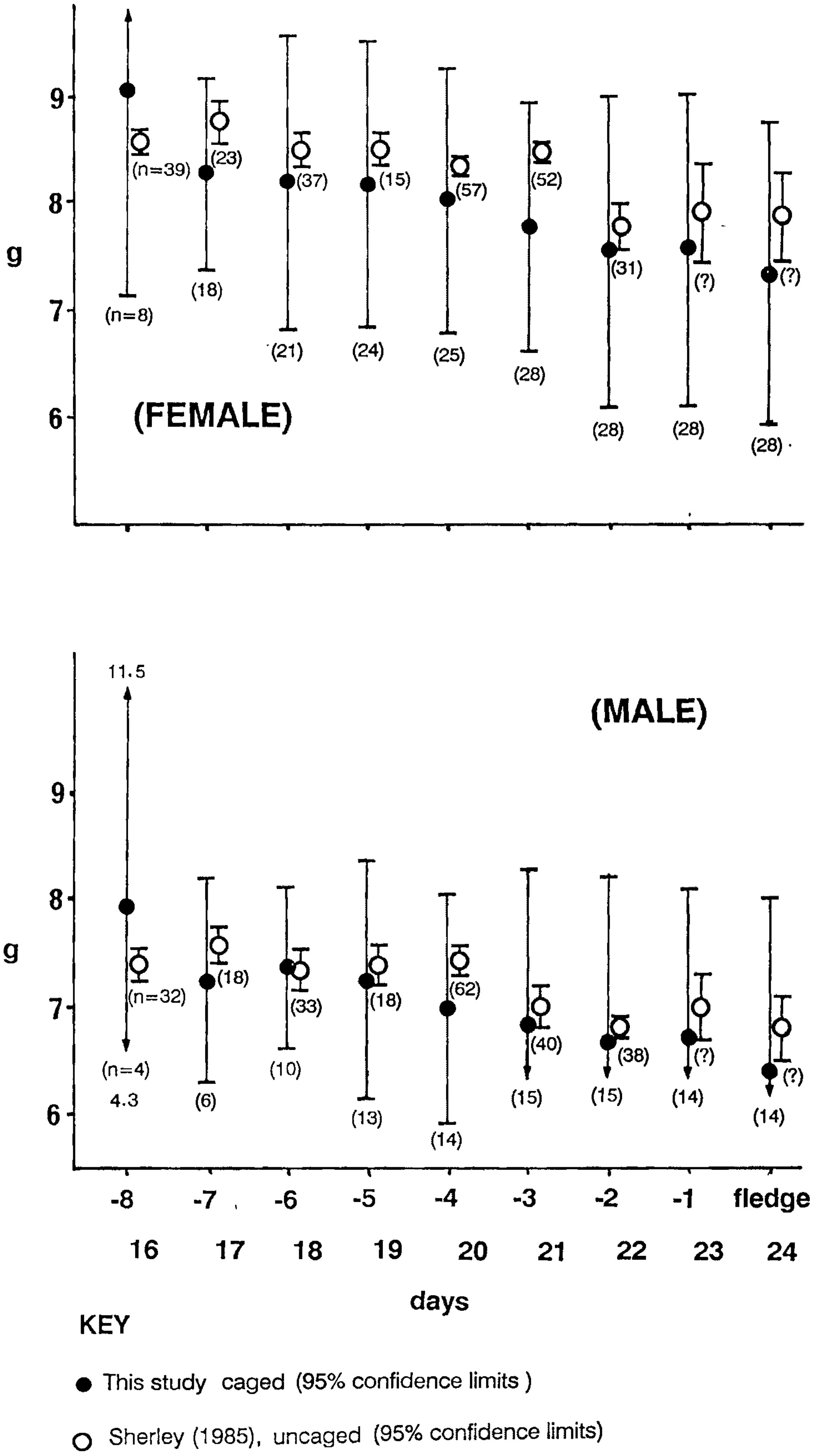


Figure 1.3 **GREY WARBLER CHICK WEIGHTS**
CAGED AND UNCAGED

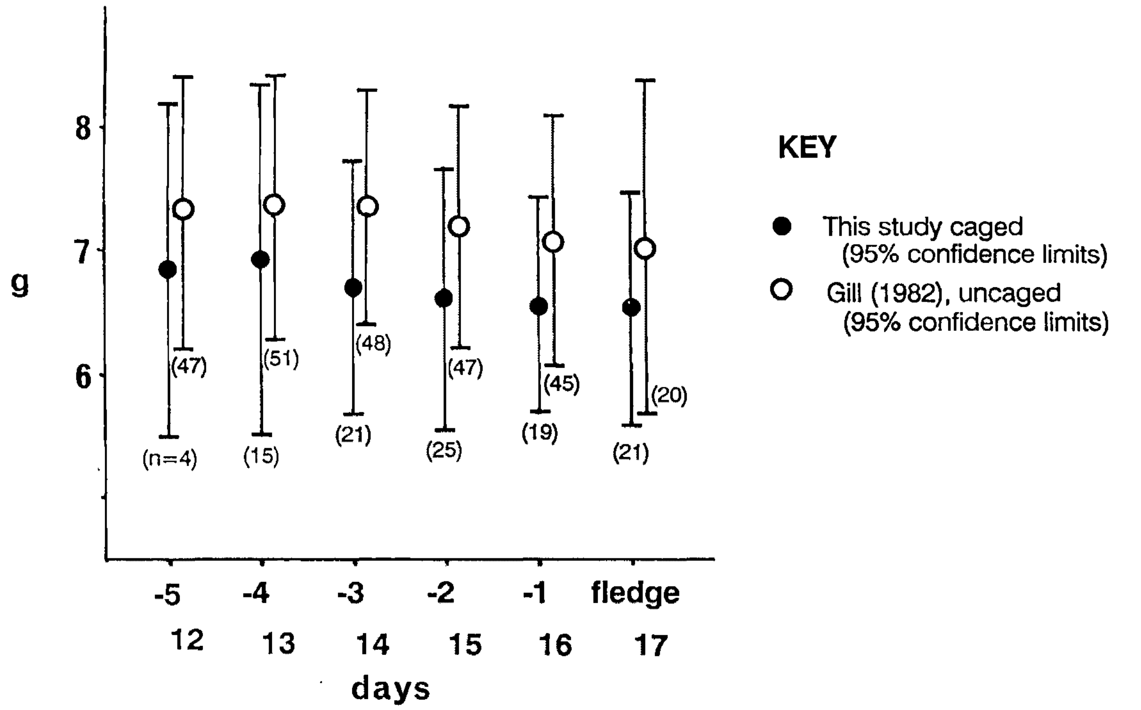


Figure 1.4 **SHINING CUCKOO CHICK WEIGHTS**
CAGED AND UNCAGED

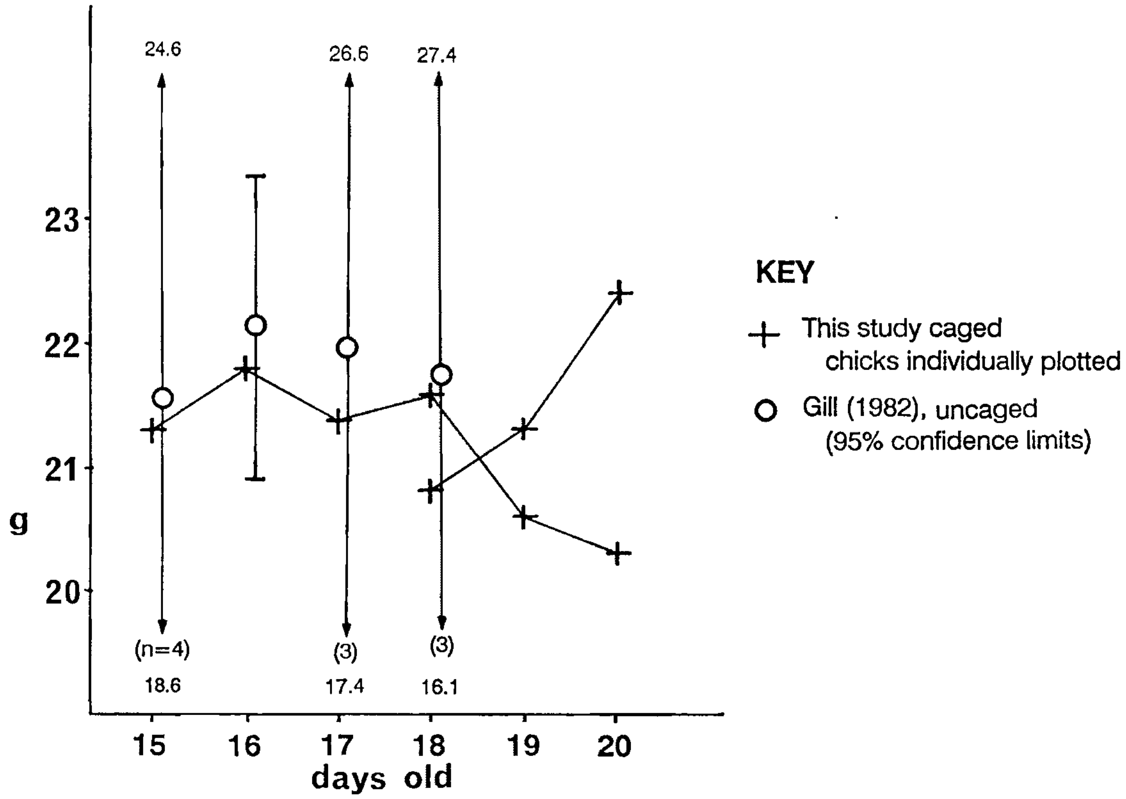
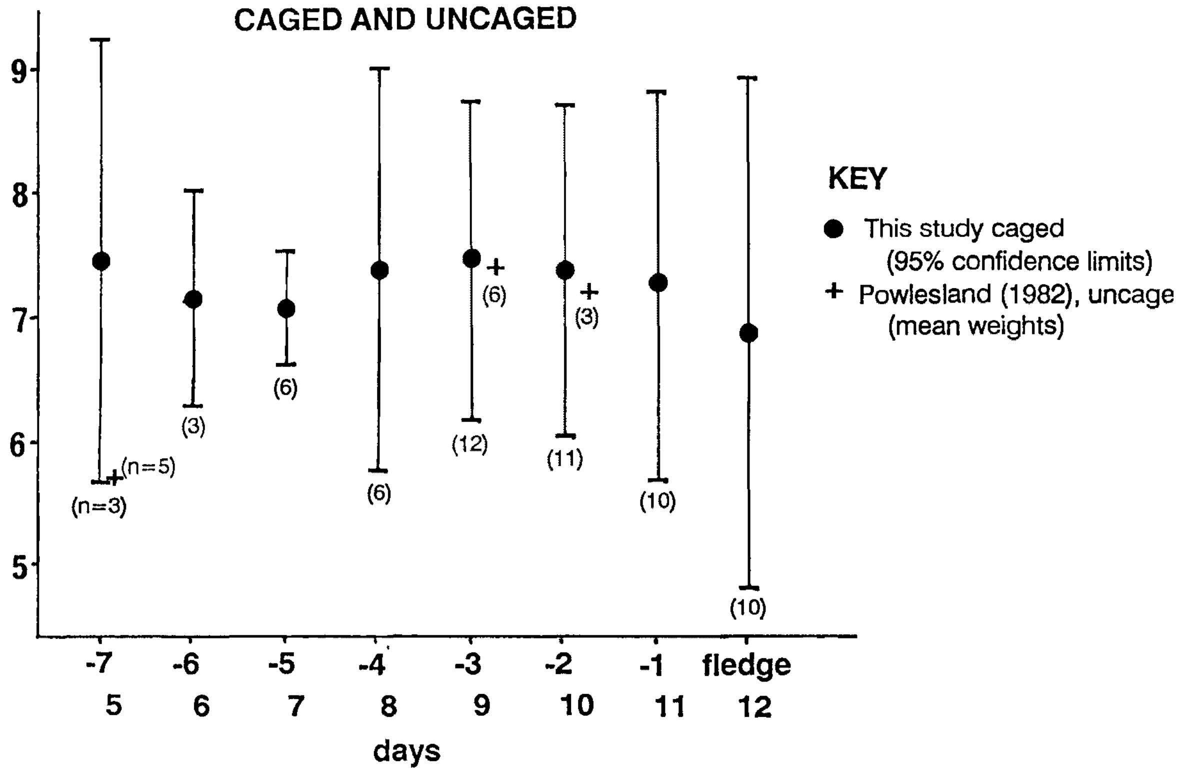


Figure 1.5 FANTAIL CHICK WEIGHTS



survived. The other nest was shredded, probably by a harrier (Circus approximans), but all chicks survived.

Nestling weight

Nestling weights in cages were slightly lower than published data indicate as average, however there is overlap of 95% intervals in all cases where variances were available and the differences are unlikely to be highly significant (Figs 1.2 - 1.5).

Feeding frequency and duration

The duration of the first 25 feeding visits of each time period was analysed using chi square test (Table 1.2). Caged nests had fewer short visits and more long visits, indicating that adults took longer to feed caged chicks than uncaged chicks

Table 1.2, Duration of feeding visits, caged vs. uncaged; (based on the first 25 feeding visits in each video period).

duration (seconds)	caged	uncaged
0 - 4	109	189
5 - 9	88	134
10 - 14	55	30
15+	73	22

$X^2 = 62.49$, d.f.= 3, $p < 0.001$.

The video monitoring was also analysed for feeding frequency based on hourly periods throughout the day. Caged nests received more feeding

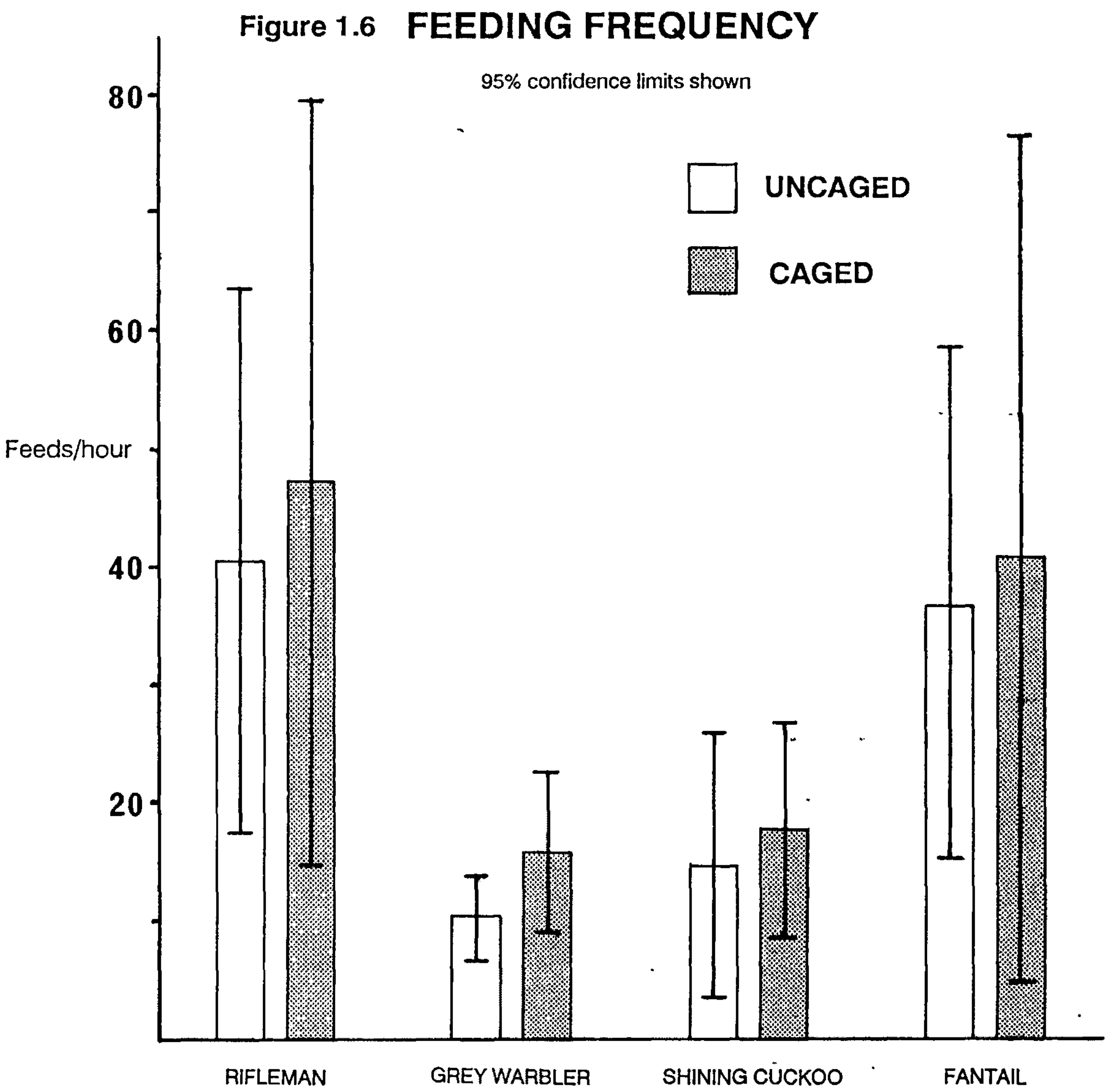


Figure 1.6 FEEDING FREQUENCY
95% confidence limits shown
UNCAGED
CAGED
Feeds/hour
80
60
40
20
RIFLEMAN
GREY WARBLER
SHINING CUCKOO
FANTAIL

visits than uncaged nests (Fig 1.6), idicating that parents compensated for food items dropped into the artificial nest.

DISCUSSION

Effect of caging on nestling mortality

Comparisons between caged and uncaged nests show that caging did not increase chick mortality for grey warbler, shining cuckoo and rifleman, but did for fantail and brown creeper. Fantail chicks appeared to fret if caged longer than their fledging age. Chicks continually attempted to escape, sometimes harming themselves. Fantail chicks seem less resilient to manipulation stress and the caging technique should be used with caution on this species. The brown creeper nest cage was not accepted by the adults who failed to feed the chick, despite taped chick calls being played at the nest. Rifleman and grey warbler adults had no difficulty adjusting to feeding caged chicks. The chicks (including shining cuckoo) handled the manipulations well.

Good protection from mammalian predators can be provided by cages since nests can be made inaccessible, for example by the placement of nests on plastic poles which cannot be climbed. However, depending on the situation, nest cages may be more conspicuous than natural nests. When using the caging technique some forethought is required as to the nest design and siting to minimise predator access.

Effect of caging on nestling weights

Chick weights tended to be slightly lower than published data. The feeding rate to caged nests was higher, possibly in compensation for the food droppped in the nest. Presumably, types of food fed were the same. Mertens (1969) showed that nests with fewer chicks used considerably more energy in thermoregulation than nests with more chicks. In the caged nest where no brooding is possible, heat loss to the relatively smooth interior is possibly greater than in a natural feather lined nest. More energy would be required to maintain body temperature and this may be the cause of the decreased body weights.

Effect of caging on feeding frequency and duration

Caging increases the time interval spent at the nest site by the parents when feeding. This observation implies that some difficulty is being experienced by the adults and chicks caused by the caging. However, the number of feeding visits in the day is significantly higher in caged nests relative to an uncaged control (Fig 1.6). It appears that adult birds are working harder to supply caged chicks with food than chicks at a natural nest. Despite food items being dropped into the nest there was still an increase in the number of feeds the chicks received. Any inefficiencies caused by nest caging is more than compensated for by more feeding visits made by the parents.

Applications of the caging method

The following indicate possible manipulations (and the species that I tested) using artificial nests: i) Nests were moved several m at a time to locations more convenient for research. Taped chick calls were sometimes used to attract the parents to the new nest location; the playback often stimulated the chicks to call (fantail, brown creeper). ii) Entire nests were removed for short periods to locations where parents would not hear chick alarm calls during handling (rifleman, cuckoo). iii) Artificial nests were taken inside on wet or stormy nights and returned before dawn (fantail). iv) Nests were suspended from a halyard in the original canopy location so they could be rapidly lowered and raised when required for weighing chicks, replacing nest linings, etc. (warbler, chaffinch). v) Caged chicks were used as a lure for mist-netting adults (rifleman, fantail, warbler).

A particularly useful application of the cage technique would be for conservation of endangered species. Once caged, the chicks are protected from predation and cannot fall or be blown out of nests. Data indicate that mortality may be reduced relative to natural nests, and may even be reduced in predator-free situations (de Hamel and McLean, 1989). Cages also readily allow the researcher to supplement the chicks' diet if necessary.

Use of the caging technique versus faecal analysis in food research

The caging technique is a non-destructive method of investigating the diets of nestlings. Food items dropped in the nest and not retrieved by adults can be collected and analysed. Traditionally, faecal analysis has been the main non-destructive method, but there are many difficulties associated with its use.

A representative reference collection of invertebrates from the birds' feeding areas is usually required to help identify the fragments in the droppings (Bryant, 1973; Calver and Wooler, 1982). This may be difficult to obtain accurately. Many faecal studies have used single droppings as units for analysis (eg. Moeed and Fitzgerald, 1982; Bishton, 1985 and 1986, and others). Moeed and Fitzgerald (1982) comment that successive faeces from a given bird differ in content as much as from samples from different individuals, implying that items are derived from relatively few food items. While faecal analysis can be representative of all that is swallowed by a bird, individual faeces may not represent a bird's total daily intake. Further, differential digestibility of arthropod species and difficulties in identifying what fragments do survive intact in the faeces means that use of this technique to accurately identify and quantify what is being fed to the bird is at best difficult and at worst impossible (Bryant, 1973; Putman 1984). Putman (1984,p 85) noted that ".. many workers consider the error to be so great that the (faecal analysis) technique becomes worthless"

Using the cage technique none of the above problems exist, as whole items or large fragments can be collected every day. However theoretically it is not as representative of what is being swallowed, and it does demand easy access to the nest. In situations where field observation is impractical due to canopy height or a birds secretiveness, faecal analysis may be the better alternative. The use of a simple presence /absence scoring for species in faecal analysis has some limited usefulness.

Conclusions

The caging method has many potential applications when studying wild birds. Mortality in caged nests need not be high if used carefully, and in many cases may be lower than in natural nests due to protection gained from predation. Although there was no short-term effect on survival of caged chicks relative to uncaged controls in most species, caged chicks could exhibit lower survival in the long-term.

Caging causes adult birds to work harder by increasing feeding rates.

Caging is not fool-proof and care must be taken in all aspects of the method, from nest design, positioning and daily checking.

PART 2 THE FOODS OF FOUR SPECIES OF INSECTIVOROUS BIRD

INTRODUCTION

In New Zealand's recent history, several endemic insectivorous (=invertebrate eating) passerines have come close to, or reached extinction. The huia (Heteralocha acutirostris) and three species of bush wren (Xenicus longipes longipes, X.l. stokesii, X.l. variabilis) are now considered to be extinct (Readers Digest, 1985), while the Chatham Island robin (Petroica traversi), and both North and South Island saddleback (Philesturnus carunculatus) only survive due to active conservation management of the remaining birds. The trend has been to manage endangered birds using island transfer programs or cross-fostering using other species. However, there is a potential risk in assuming that one insectivorous bird will survive in any location or on the same food items as another species. Feare (1984) noted that our knowledge of avian nutrition is limited and the precise requirements for a 'balanced' diet for any wild bird are not known. Requirements will also vary throughout the year and during the birds life.

Collecting quantitative and qualitative food data from wild populations is a major problem, especially when the birds and their prey are small. Furthermore the ornithologist's knowledge of entomology is often limited, and invertebrate food items may be identified to only broad categories. While this presents a simple overall picture, many invertebrates are highly specific in their distributions, habitats, and daily or seasonal timing (Betts, 1954, 1955). Consequently, valuable knowledge about bird feeding habits can be gained if specific food item information is available.

Hartley (1948) reviewed many of the methods of collecting and analysing food items for birds. Methods can be divided into two groups, direct and indirect.

Direct methods of collection rely on manipulations to obtain samples of foods eaten. Examples include the analysis of stomach and gut contents by dissection (Van Koersveld, 1950; Betts, 1955; Coleman, 1977; Sherry, 1984; MacMillan & Pollock, 1985 and many others), emetics (Prys-Jones et al. 1974; Zach and Falls, 1976), flushing the digestive tracts of both adults and nestlings with saline (Moody, 1970), neck-collars or ligaturing nestlings (Kluyver, 1933; Coleman, 1977; Johnson et al. 1980), bolus removal (Hails & Amirrudin, 1981) and artificial chick gapes (Betts, 1954 & 1956). Direct methods have traditionally been thought to be more accurate. However, hard parts may be preferentially retained in gut samples (Hartley, 1948). Coleman (1974), studying starlings (Sturnus vulgaris), found that 15 minutes was enough to digest some soft bodied items. If stomach contents are to be analysed, then birds must be killed and analysed immediately after the food is consumed. Other researchers have used serological techniques and radio-active isotope tracing especially in food chain research (Des Marais, et al., 1980). While both methods are potentially useful, the technologies involved are complex and specialised. Many direct techniques, may be unintentionally stressful or even fatal to the bird being studied, especially small birds (Zach and Falls, 1976). When studying rare or endangered species the practical aspects of a technique must be considered.

Indirect methods for gathering feeding data involve little disturbance of the bird under study. Monitoring by eye (Moreau, 1947; Tinbergen, 1960; Sherley, 1985; and others) or camera (Dunnet, 1955; Royama 1966, 1970) and faecal analysis are common ways to gather feeding data. Faecal analysis has been the most widely used indirect technique for investigation of the types of foods eaten by insectivorous birds (Bryant, 1973; Davies, 1977; Moeed & Fitzgerald, 1982; Bishton, 1985 & 86; Ralph et al. 1985 and others). This method relies on hard parts in the meal surviving in an identifiable form to be passed out in the faeces. No specialised technology is required for faecal collection, but skill is needed for analysis. Indirect methods minimise intrusions on the study species but may forfeit accuracy, being largely dependant on observers and their interpretations.

This study was designed to find out what invertebrate species were fed to a selection of nestlings. The caging technique (ch. 1) provided extremely accurate food item identification without the manipulation stress of most direct methods.

The study area.

The study site was located in 20.25 hectares of successional kanuka (<u>Kunzia</u> <u>ericoides</u>) forest, located on flat coastal plains adjacent to the Kowhai Bush reserve, 7 km inland from Kaikoura (NZMS1 S49 903951). The canopy averaged 5.2 m in height and was almost clear of undergrowth due to the presence of grazing domestic farm stock and lagomorphs.

The study birds

Three species of passerine and one species of cuckoo were studied to identify items in their diet. These species make up four of the five arborial gleaner / flycatching insectivorous bird species living in the study area. Other species make use of invertebrates at certain times but obtain the bulk of their food from sources outside the kanuka forest.

The South Island rifleman,(<u>Acanthisitta</u> <u>chloris</u> <u>chloris</u> Xenicidae) (mean body weight, males 5.98g. n = 8: females 6.9g. n = 11 *), grey warbler (<u>Gerygone igata</u> Muscicapidae) (6.49g. n = 41 *), fantail (<u>Rhipidura fuliginosa fuliginosa</u> Muscicapidae) (8.02g. n = 12 *) and shining cuckoo (<u>Chrysococcyx lucidus lucidus</u> Cuculidae) (23.1 g. n = 16 frozen specimens, Gill, 1980) are all endemic to New Zealand, the latter three species having close relatives in the south-west Pacific region (Readers Digest, 1985).

[* = average adult mass , unpubl. Kowhai Bush data.]

METHODS

Nests

All nests belonging to the study species were frequently checked so that chick ages were known. When the nestlings were several days away from fledging age, they were colour-banded and the nest assigned to one of two treatments. Either the chicks were replaced in their natural nest as a control, or caged (ch. 1). During the 1986-87 season all nests were caged, while during the 1987-88 season an alternated caged and uncaged nest assignment was used.

Food collections

The caging technique meant the chicks were caged in situ at the nest. Caging partially obstructed adults feeding their chicks. A proportion of food items were dropped into the caged nest but remained untouched by the chicks. Most faeces also remained in the nest although a small proportion were removed by the parents. Caged nests were lined with paper which was replaced daily allowing all collected food items and faecal matter to be easily and completely removed. At the same time chicks were weighed as a measure of individual well-being. Food items were labeled and stored in 70% alcohol, while faeces were dried and stored separately.

Food items collected daily were identified to family, genus or species. All items were counted, labeled and stored in vials. The species lists (Appendix 2) were derived from these collections. A representative number of items were oven dried (60^{o} C for 15 hr) and then weighed using a Cahn 21 automatic electrobalance (mg to 3 decimal places). All collected items from each bird species were combined to give a larger data base.

Video

During 1987 and 1988 seasons a sample of nests were monitored during daylight hours using a video camera/recorder (Hitachi VM-500E), with attached character generator (Hitachi VM-CG20E) including a stopwatch function. The camera was set up in the field to record all activity at the nest for 3 hours at a time. The C180 video tapes were replaced four hourly, with the camera remaining off for the intervening hour between tapes. Video monitoring was started before dawn and generally followed a standard pattern, 0500 hours - 0800, then 0900 -1200, 1300 -1600 and 1700 -2000 hours (NZ summer time) giving 12 hours of recordings per day. Since not all trips to the nest result in chick feeding, only those trips where feeding could be seen to occur were used in later analysis. To minimise the effect of any disturbance caused at the nest while setting up the video camera, recoding of feeding frequency (feeds per hour) was begun from the first feeding visit. The number of feeds in each hourly period was noted and their mean and 95% confidence limits calculated.

RESULTS

Over the two seasons a total of 37 nests were caged to collect food items, involving 99 chicks (rifleman 62.20%; fantail 16.54%; grey warbler 14.17%; shining cuckoo 7.09% by number). Over 2000 individual invertebrate items were collected from 128 daily food item assemblages (Appendix 2).

Mean food item weight

Fig 2.1 shows that the heaviest average items were collected from nests of grey warbler chicks, averaging 6.445 mg dry weight. Shining cuckoo chicks, also in warbler nests, received on average slightly smaller food items, 6.116 mg dry weight. Rifleman had an average dropped food item weight of 4.277 mg, and fantails showed the lowest average weight of 3.820 mg. There was no significant difference in mean food item weight between all four species (Kruskal-Wallis Anova, $p > 0.05$)

Composition of food item collections

The overall content of the collections varied depending on the species being caged. Fig 2.2 gives the overall composition of the collected items in terms of numbers and weight. For the comparison between weight and numbers, only insects for which weights were obtainable were used (Appendix 3).

Collections from rifleman nests (519 weighed items, representing 98.1% of the total collected) showed the majority of items were moths with over 54% of these belonging to one order, the Pyraloidea. By mass this group made up 26% of the food collected. The remaining items (<20%

Figure 2.1 MEAN COLLECTED ITEM WEIGHT
Sample size = number of food items
(95% confidence limits)

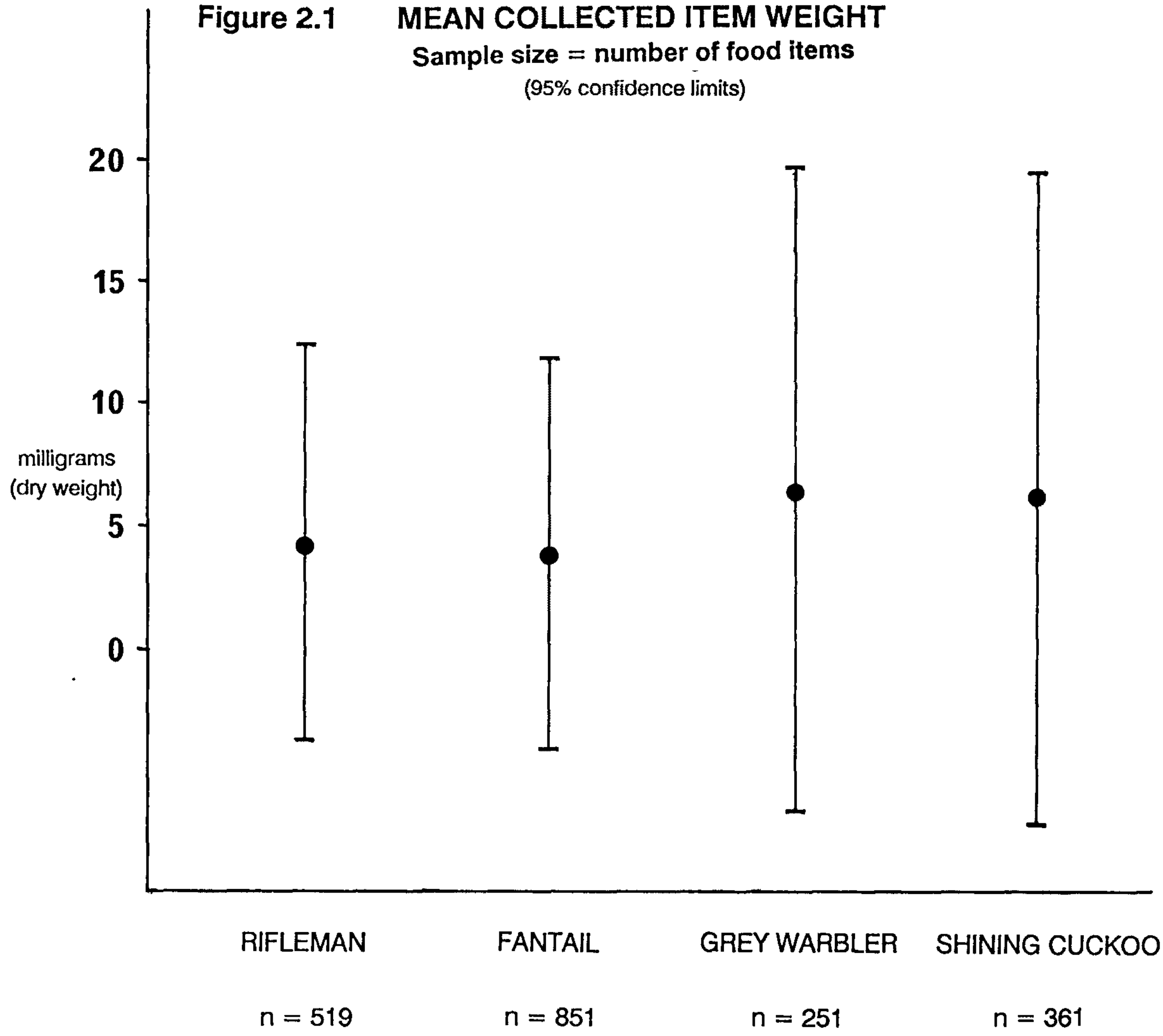
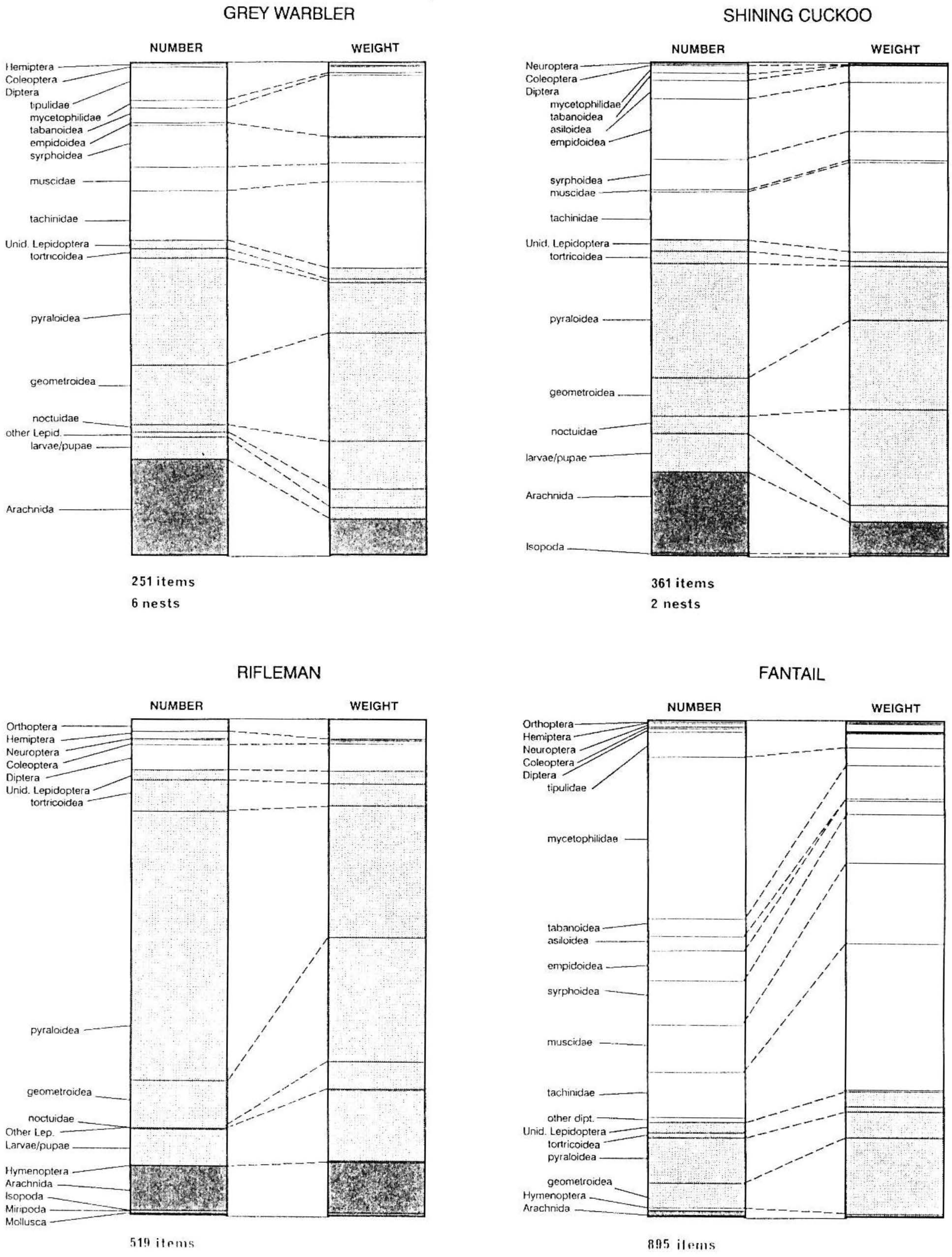


Figure 2.2 PERCENTAGE COMPARISONS OF ITEM COMPOSITION BY NUMBERS AND WEIGHT FOR ALL SPECIES



of the total) included spiders, flies and members of several other groups.

All items found in the fantail nest collections (851 weighed items, 95.1% of total number of items collected) were flying species, the main group (over 80%) being Dipterans. Mycetophilids (Diptera) made up over 30% by number but in terms of weight less than 3%. The only other group with a significant contribution were the lepidopteran adults.

The caged grey warbler nests provided two sets of data depending on whether a shining cuckoo had successfully parasitised the nest or not. Adult moths, flies and spiders were the main groups collected from nests with warbler chicks (251 weighed items, 98.4% of total), with low overall diversity. When cuckoo chicks were in the nest (361 weighed items, 99.2% of total) there was a similar range of items with the same groups of lepidoptera, diptera and arachnida being represented.

Using the complete data (Appendix 1), samples were analysed for resource partitioning based on 5 categories. A two sample T-test showed a significant difference between fantails and other species when comparing numbers of diptera ($p < 0.001$). No significant differences were seen in the numbers and species of items collected from nests containing grey warbler and shining cuckoo chicks.

For all bird species approximately a third of the collected items, by number, contribute two thirds of the food by weight.

Video monitoring

Video confirmed that both rifleman and warbler adults brought single items to the nest while occasionally some of the larger moths were fed in two segments. Fantails however frequently collected several items before feeding the chicks.

Comparisons were possible between species and between caged and uncaged nests to assess how closely the cage collections reflected otherwise natural nests.

Feeding visits to caged nests were consistently more frequent than visits to uncaged nests (Table 2.1). This indicates that adults were attempting to compensate for the numbers of items dropped by bringing more food.

Table 2.1 FEEDING VISIT FREQUENCIES FOR THE STUDY SPECIES, CAGED AND UNCAGED, FROM VIDEO MONITORING.

	date of video	# video periods (n)	number of chicks	feed visits per hr	s.d.	other authors
RIFLEMAN uncaged	11/11/88	8	3	40.66	9.97	27.8 f/hr (Sherley,85)
RIFLEMAN caged	9/11/88	11	3	47.11	14.77	
WARBLER uncaged	18/11/88	10	2	10.27	1.62	18 f/hr (Gill, 1980)
WARBLER caged	20/11/88	12	2	15.91	3.16	
S.CUCKOO uncaged	8/01/88	9	1	14.78	4.98	15 f/hr (Gill, 1980)
S.CUCKOO caged	30/12/87	12	1	17.79	4.17	
FANTAIL uncaged	20/10/88	11	3	36.84	9.83	
FANTAIL caged	5/12/87	2	4	40.82	12.13	

Notes: 1) Assuming no night time feeding, when it is too dark for the video camera. 2) For all species except fantail, feeding visits correspond to items fed. Fantails frequently feed multiple items at one visit.

The numbers of items dropped into the cages is variable. Different bird species seem to drop differing numbers and there are often differences between successive nests and days. The number dropped may be partly due to the design of the caged nest, and partly the individual birds. Overall, rifleman dropped the fewest items per day, and warblers with a cuckoo chick and fantails dropped the most (Table 2.2).

Table 2.2 MEAN NUMBER OF DROPPED ITEMS IN CAGED NESTS PER DAY

	# of nests in sample	# of daily collections	range of #'s collect /day	mean of #'s collect /day	S.D.
Rifleman	16	103	0 - 32	5.34	7.16
Grey warbler	6	19	1 - 46	13.32	13.77
S.Cuckoo	2	9	6 - 91	40.67	26.99
Fantail	5	21	9 - 101	42.10	25.00

Combining these results with the feeding rates gained from the video gives an indication of how representative the collections from the nests are (Table 2.3).

Table 2.3 NUMBER OF DROPPED ITEMS AS A PERCENTAGE OF ALL THAT IS FED.

	feeding rate f/h (caged)	* mean day length(hr) for video	extrapolated feeds/day/nest (caged nest)	mean #'s collected/day (from table *)	percent dropped
Rifleman	47.11	(Nov) 14.6	687.9	5.34	0.78%
G. warbler	15.91	(Nov) 14.6	232.3	13.32	5.73%
S. cuckoo	17.78	(Dec) 15.3	273.0	40.67	14.90%
Fantail	40.82	(Dec) 15.3	624.5	42.10	6.74%

Notes; Assumes single items only brought to the nest (not true for fantails).
* = data from Powlesland (1980), cited by Sherley (1985).

Using the number of feeds taken to an uncaged nest in a day and the mean item weight collected for each species, one can calculate the number and weight of feeds given to each chick assuming all chicks receive an even proportion of the fed items (Table 2.4).

Table 2.4 WEIGHT OF FOOD RECIEVED BY INDIVIDUAL CHICKS IN ONE DAY.

	feeding rate f/h (uncaged)	* mean day length (hr) for video	extrapolated feeds/day/nest (uncaged)	# of ch.	feeds per chick	dry wt (mg) per chick per day
Rifleman	40.66	(Nov) 14.6	593.6	3	197.9	846.3
G. warbler	10.27	(Nov) 14.6	149.9	2	75.0	483.4
S. cuckoo	14.77	(Jan) 14.9	220.1	1	220.1	1346.1
Fantail	36.84	(Oct) 13.3	490.0	3	163.3	623.9

* = data from Powlesland (1980), cited by Sherley (1985).

Shining cuckoos eat most in a single day followed by rifleman, fantails and warblers. The weight of food collected from the four species follows the same trend as the fledging weight of those species (ch. 1).

DISCUSSION

How representative the collected items are is an important aspect to the success of the cage technique in providing complete food requirement information for insectivorous birds. Caging significantly increased the number of feeding visits made to the nest, relative to an uncaged nest (Table 2.1). The causes for this are uncertain although the chicks' thermoregulation could be a factor. As no parental brooding is possible, heat loss, particularly at night, could increase chicks' food demand (Mertens, 1969).

For a caged nest it is reasonable to assume that dependant on the species of bird, the more feeding trips made to the nest the greater the number of items that will be dropped. Further, it seems probable that a greater number of a particular type of dropped item would reflect a greater preponderance of that item being fed. It might be suspected that a sample could be misrepresentative with "slippery" species being preferentially dropped. One can see from the lists of dropped species (Appendix 2) that there is a large number and wide range of invertebrates collected, suggesting that what is being collected is representative of what is fed.

Insect availability

Kanuka is the single dominant canopy species in the study area. Limited plant diversity contributes to a narrower range of invertebrate food resources for arboreal insectivorous birds (Jackson, 1979). Blancher & Robertson (1987) noted that daily insect abundance was primarily related to temperature and date, while annual differences appeared to reflect the precipitation during the previous year. Since insect abundance can be correlated with climate (Hurnard, 1978), and if breeding can be delayed when the food availability is low (Sinclair, 1978; Blancher & Robertson, 1987), one could predict a late season was an indication of a poor food supply. Sherley (1985) thought the most likely cause of second clutch failure in rifleman was drought. Gill et al. (1983) suggested annual drought events might be the cause of shortened breeding seasons of warblers in Kowhai Bush. The beginning of breeding was not delayed in either year of the present study, however subsequent breeding duration and success was variable (Appendix 4). Rifleman productivity dropped off sharply during the second summer possibly due to food shortages brought about by the drought conditions during the previous season.

What is selected?

Profitable prey can be defined as being large and/or abundant, while least profitable prey are small and/or rare (Bryant, 1973). The more selective a forager is over what it will take to the nest, the longer the search time (Krebs et al., 1987). With the demand for food at the nest, insufficient time exists to forage for optimal items only (Nadav, 1987), and so less optimal items may form the bulk of the food collected. As items are brought back to the nest singly or in low numbers, the numerical abundance of items indicates the effort involved in food collection. Weight of items brought back to the nest is a better indicator of food value importance. Pyraloidea are the most common group of items found in 3 of 4 bird species, but the low body mass of these items means they make up a relatively small proportion of the total weight of food items. The numbers imply that Pyraloidea are easily caught, while being less profitable in terms of food weight than some other groups.

Resource partitioning between potentially competing species living within the same area has often been demonstrated (Hespenheide, 1971; Verbeek, 1975 and others). Little difference is seen in the average weight of items collected by each of the bird species (Fig 2.1). Statistical analysis confirmed that resource partitioning does exist for some insects between the three foraging species (Fig 2.2). In Kowhai Bush, where there is only one canopy species, little spatial variation is possible between the birds, as suggested by Holmes & Robinson (1981). Clearly resource partitioning in this area seems unrelated to habitat variation. Bird size (weight and strength, wing and beak size and shape) has the largest effect on the prey a bird can utilise (Hespenheide, 1971; Pearson, 1975). Smaller bird size may mean greater manoeuvrability, but may also mean some prey are too large to handle (Pearson, 1975). Schoener (1968) noted that small predators are easier to feed, body size being ultimately related to the overall energetics of the predator. Based on the adult body weights of the three bird species, fantails might be expected to take the largest items, whereas the grey warbler, the lightest of the birds, predictably would take the smallest items. This was not the case (Fig 2.1). Partitioning is more likely to be on the basis of method of prey capture. Fantails only eat flying insects, with numerous small, highly motile, day active species represented in the collections. Rifleman feed by gleaning trunk zones and grey warblers by gleaning and hover picking amongst the canopy (Dean, 1989). A high proportion of rifleman and grey warbler diets are made up of moths and caterpillars, which are relatively large and slow moving.

In conclusion, it appears that what is being dropped is close to being representative of all that is fed.

Feeding comparisons between this and other studies

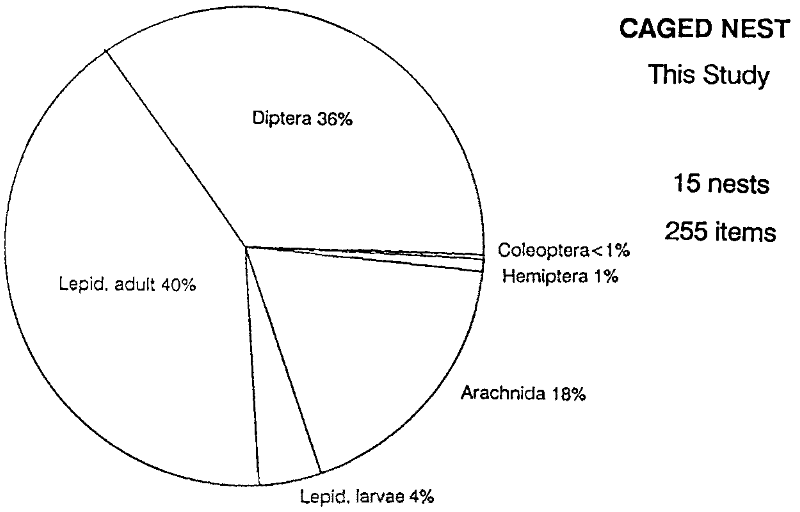
Fig 2.3 (a - c) presents the results of this study redrawn to compare it with the results of other studies.

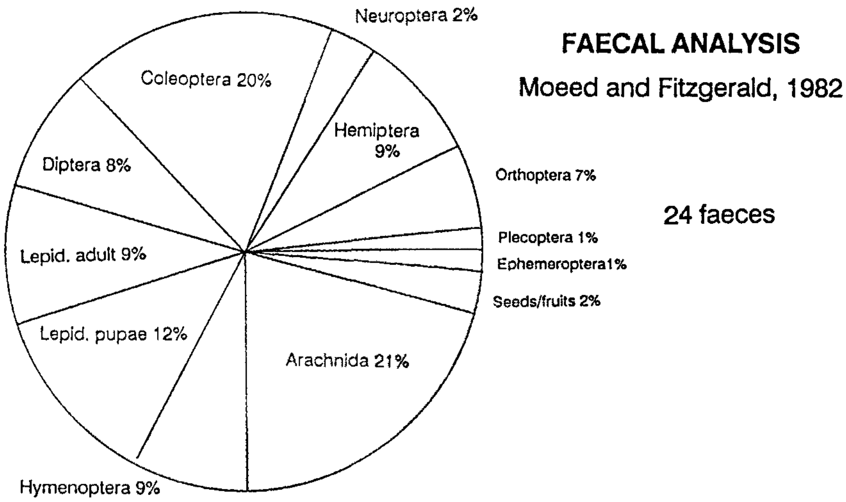
Analysis of stomach contents is potentially the most accurate method of analysing diets. Gill (1980) dissected grey warbler chicks from Kowhai Bush. However chicks can die from a variety of causes most of which are liable to affect the chicks ability or desire to feed. Cameron (1985) dissected adult *Ripidura fuliginosa* (grey fantail) in Australia. Both studies showed that the bulk of items fall within one or two invertebrate groups. A similar emphasis towards groups is seen in caged nest samples. The actual composition differences in part represent habitat differences. For example the high number of hymenoptera (flying

Figure 2.3(a) **FOOD ITEM COMPOSITIONS**

CAGED NESTS VERSUS OTHER METHODS

Grey Warbler





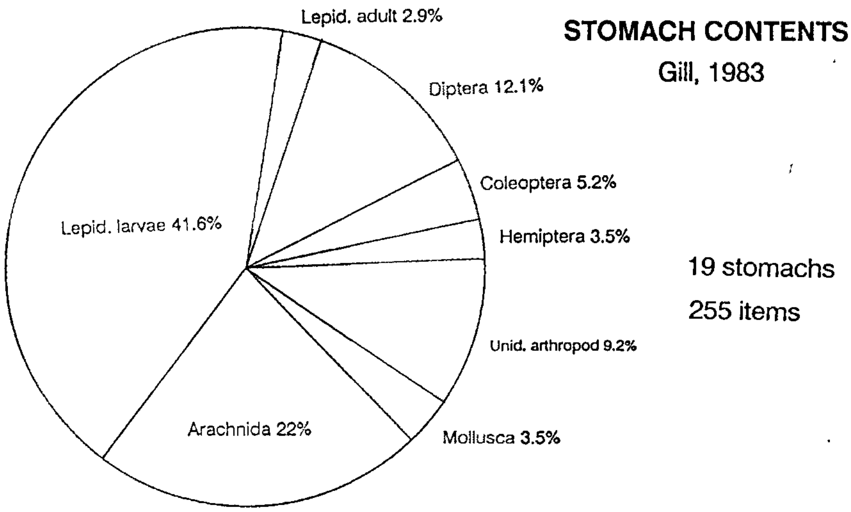


Figure 2.3(b) FOOD ITEM COMPOSITIONS
CAGED NESTS VERSUS OTHER METHODS

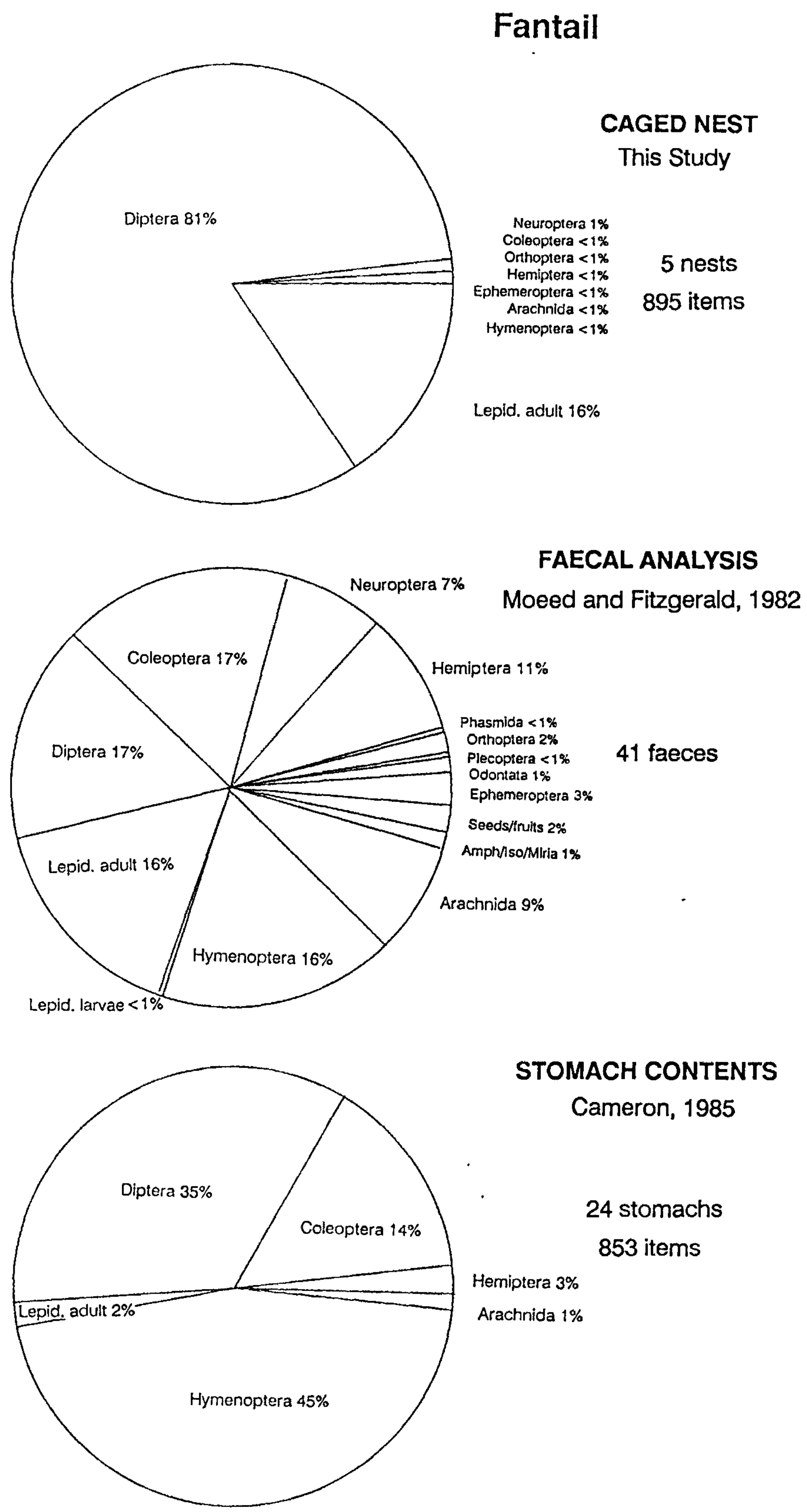
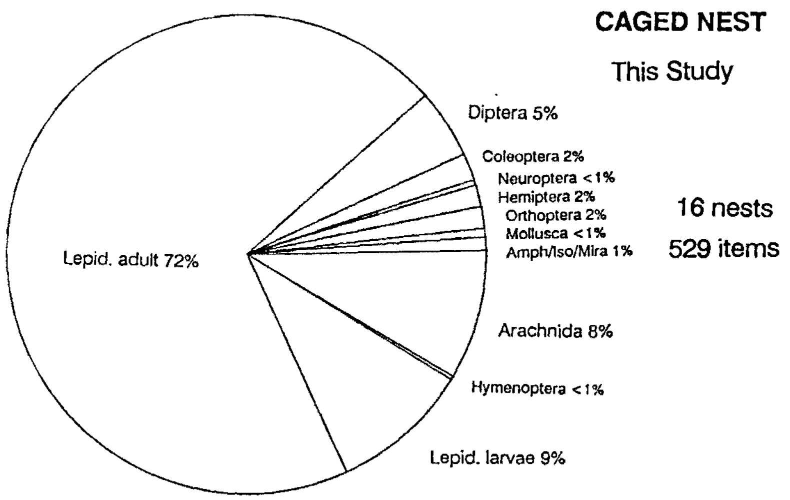
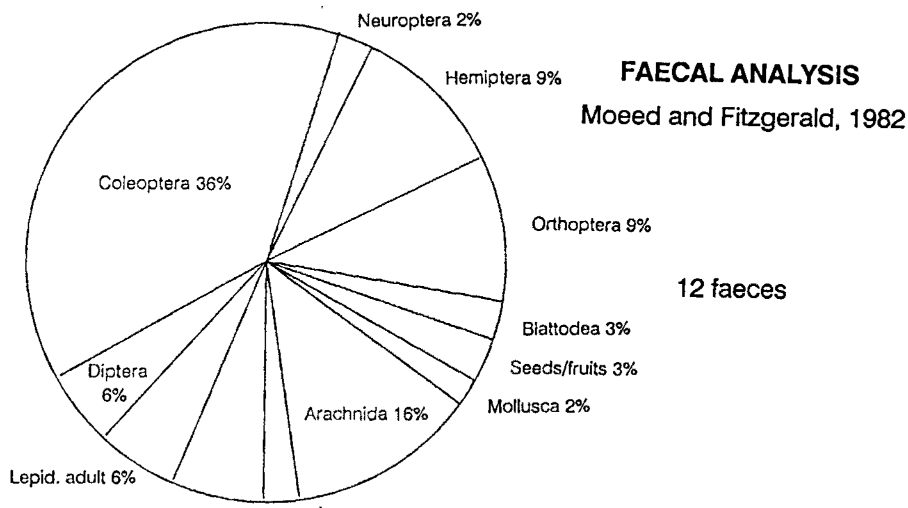


Figure 2.3(c) FOOD ITEM COMPOSITIONS
CAGED NESTS VERSUS OTHER METHODS

Rifleman





ants in this case) present in Camerons data probably represents their relative abundance in Australia. Gill's warbler chicks (which all died of natural causes) were collected from Kowhai Bush from a more diverse habitat than that used in the present study. Lepidoteran adults seem to be represented in a very low percentage. Possibly this is a result of the limited time some items survive in stomachs, which is a recognised problem associated with this method (Coleman, 1977).

Faecal analysis was used by Moeed and Fitzgerald (1982) in a study of the food of arboreal insectivorous passerines in the Orongorongo Valley near Wellington. Droppings were analysed on a presence / absence basis only. To compare individual item proportions with such data is inaccurate, but as a guide this comparison assumes that a common or preferred item should appear in nearly all faeces and rarer ones in fewer. Samples collected from the Orongorongo Valley show that coleoptera and arachnida are the most common items identified in both rifleman and grey warbler faeces. Beetles, flies, moths and wasps are all of similar importance in fantail samples. However, faecal analysis using a presence / absence scoring gives the impression that all the major groups are close to being equally important, whereas other methods show one or two groups are predominant. Further, a bias towards coleoptera and other invertebrate groups with hard structures is found in the results of faecal analysis, compared with results from stomach content analysis and caging. This is a common problem with faecal analysis (Putman, 1984). The results from the Orongorongo Valley are not representative of the complete diet being based on relatively few droppings which individually are derived from small numbers of food items.

These problems do not imfluence the results of the caging method. Habitat and methodology are the two main causes of variation in results.

As habitat varies from study to study, the method of analysis must be easily applied and representative of the diet.

Use of the cage technique in the management of insectivorous birds

The cage technique offers an uncomplicated method of assessing the foods of small birds. Caging enables the collection of large numbers of items and thus has the ability to be representative of the diet of chicks. Once a good knowledge of the type and quantity of foods of birds is obtained management practices such as cross fostering or captive breeding are more likely to succeed. Before island transfers are made, habitat assessments could be made specifically for the availability of suitable food items for particular bird species. In combination with a simple video monitoring program, added detail relating to parental effort and the overall quantity of food required by chicks can be obtained. Because caging is non-destructive when used with care, it could be especially useful for the management of endangered species.

PART 3:

THE ROLE OF HABITAT, POPULATION DENSITY AND NEST LOCATION IN BREEDING SUCCESS OF THE GREY WARBLER (*Gerygone igata*) AND FANTAIL (*Rhipidura f. fuliginosa*).

INTRODUCTION

Breeding success in birds is fundamentally related to the nest, and the caring of the chicks, this study looked at various parameters which might affect nest success. Population density, territory size and structure, nest positioning within the territory, and the sex role investment put into nesting and defence by the parents, were all looked at in relation to nestlings fledged in the season.

For the purposes of this paper territory (defended area) and home range are combined, as territory plots based solely on acts of defence would have been impracticable.

Territories can be quantified in terms of the physical parameters of the habitat they contain (eg. area and tree structure), or in biological terms (eg. food resources or predatory influences).

The territorial area of a wild bird is not always easy to measure precisely. In this study an accurate grid system was used to plot the territories of two species of small insectivorous birds, the grey warbler (*Gerygone igata*) and the fantail (*Rhipidura fuliginosa fuliginosa*). Both species hold "A" type territories, where the defended area is used for mating, nesting and feeding over the breeding season (Nice, 1941 cited by Pinkowski 1979; Hinde, 1956). Both species are multibrooded within the season. Grey warbler are also hosts to shining cuckoo (*Chrysococcyx lucidus lucidus*) parasitism.

Studies of breeding native New Zealand passerines have suffered from two main problems. Firstly, most have been restricted to tall native evergreen forest, where both birds and nests are hard to locate and track (Gill, 1980), and secondly, monitored nests tend to be the lower, more obvious ones. Meaningful comparisons may suffer because of the effects of locational factors such as predation or exposure to weather. By using a carefully chosen study area with a low canopy height and a grid system, these problems were eliminated and almost all nests regardless of their positions were found. The low canopy also allowed nests to be easily checked.

METHODS

Study area

The study area was located on 20.25 ha of flat farmland north of Schoolhouse Road, and bordering the Kowhai Bush Reserve ($42^{o}23'$S; $173^{o}37'$E; NZMS1, S49 903951), 7km inland from Kaikoura. A successional growth of Kanuka (Kunzia ericoides) was the dominant vegetation type growing to an average height of 5.2 m and interspersed by narrow farm tracks and grassy clearings. Little undergrowth existed due to the grazing pressure of domestic farm animals and lagomorphs.

Study grid

A grid was measured out with 30 m intervals between points. An alpha-numeric convention was devised and trees were marked using aluminium strips (venetian blind). The openness of the understory and flat terrain meant that most markers could easily be seen and read using binoculars at a distance. Any position within the study area could be defined to within 2 m in relation to the marker points.

Banding

During both 1986-87 and 1987-88 seasons an intensive banding program was carried out. Adults were generally caught using mist nets set at dawn. Twin speakers and a switching system with pre-recorded bird calls on cassette tapes were used to attract birds into the nets. Chicks were banded in the nest prior to fledging.

A sequential four band combination (two on each leg) was used, made up of coloured plastic bands and a metal band which was also used as a colour. All adult birds received unique band combinations while nestlings in a single nest were given the same leg band combination (survival in the first year is known to be low, Gill 1980; Powlesland, 1982).

Home range (territory) size

Home ranges were defined by following known birds within the study area. All except one fantail was banded and sixteen of the 17 territory holding male warblers were colour banded along with 9 of their 15 mates. Sightings of unbanded birds were used if the bird was plainly associated with a particular nest and within the confines of what was known of the territory. Following individual birds often allowed a continuous map of home range use to be built up in time and space. Other plots were made from sightings of individuals at single localities. Grey warbler plots were made using the locations of male birds (being the main territory defender) or the female when her movements were closely associated with those of the male, eg. during nest building and egg laying periods. Fantails do not show such clearly defined sex roles and either bird was used for territory plots. Late in the season birds will often make excursions well outside their normal range and these were not used for the plots. Between 19 and 141 field sightings were used when plotting each home range onto graph paper, and an enclosing perimeter was drawn between adjoining points on the outside of this area. The plots represent minimum areas used by the birds.

The territory areas were calculated using a cut-out and weigh method. The areas defined by the plotted positions were cut out from paper and weighed using a Mettler PE 360 (Delta range) electronic balance, and compared to a standard area of the same paper. These constituted the base territory areas.

As treeless areas are unused by warblers for feeding or nesting, they do not form part of the defended warbler territory. A second, adjusted territory area was calculated for each pair of birds to allow for the local distribution of trees within the area. Warblers using trees around open spaces had territory areas adjusted downwards. Similarly, territories bordering the bush edge were extended to coincide with the natural boundary. Fantails however, are aerial feeders and will catch flying insects in open areas. Therefore no adjustment was needed to territory sizes.

Measurements were taken at all grid points of the canopy height, tree height (to the nearest 0.5m) and trunk diameter (D.B.H., to nearest 0.5cm) giving an overall coverage of the study area. Measurements of grid marked trees in specific home ranges were used to calculate an average habitat structure.

Nest finding

Warbler nests are camouflaged and often well hidden. Nests were generally found by finding and following a male (located by his song) until the female was sighted and then she was followed back to the nest. Several attempts were often required before the nest was found. Fantails share nest building and incubation and either bird could be tracked to the nest. Being able to identify the birds in every territory meant I knew which nests were still to be located.

Nest outcome

Regular checks of all nests were made using a ladder. Nest contents and any activity at the nest site were recorded. Egg laying, clutch sizes and hatching dates were used to calculate chick ages and predict fledging dates. Nest records were updated daily.

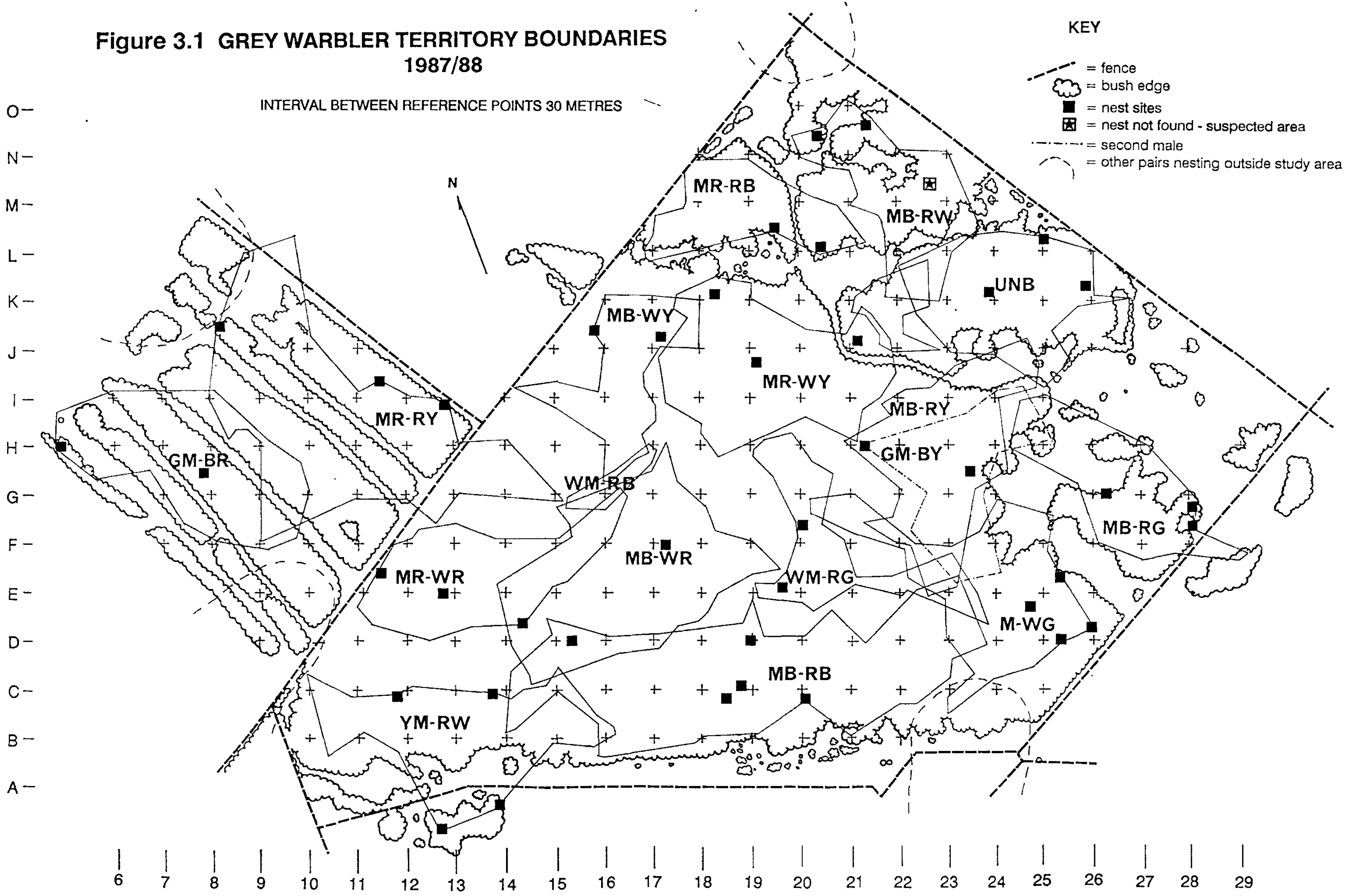
Nest failure could usually be put down to predation (avian or mammalian) or climatic effects (wind or rain). The methods used for determining the cause of failure were based on characteristic signs. Avian predators tend to pull the nest up onto the canopy before shredding it, and sometimes it is entirely removed. Mammalian predation typically leaves the nest trailing in pieces downwards from it's original position, or holes are found burrowed through the nest. Wind may cause eggs to be flung out of the nest or cracked by the jolting effect of the swaying trees, while the nest remains intact. All nests were checked after high winds so that damage could be accounted for.

RESULTS

Within the 20.25 ha study area, 15 grey warbler territories and 4 fantail territories were plotted (Fig. 3.1 and 3.2). All except two nests were found, one from each species.

Figure 3.1 GREY WARBLER TERRITORY BOUNDARIES 1987/88

INTERVAL BETWEEN REFERENCE POINTS 30 METRES



GREY WARBLERS

Home range size

Warblers will wander onto another birds territory; some overlap occurs when all territories are plotted (Fig 3.1). Territory sizes for warblers ranged between 1144m^2 for a male without a female to 20204m^2 for a particularly aggressive bird (Table 3.1).

Table 3.1 AREAS, CANOPY AND TREE STRUCTURE FOR WARBLER HOME RANGES.

Terr. code	male bands	territory area base (ha)	territory area adjustd (ha)	# plots used	mean canopy ht.(m)	mean tree ht.(m)	mean tree DBH.(cm)
C12	YM-RW	1.1305	0.9959	46	5.64	5.53	6.75
C19	MB-RB	2.0204	2.1650	95	5.15	4.93	5.43
D15	MB-WR	1.6738	1.6738	141	4.90	4.51	5.31
D26	M-WG	0.9925	1.1036	46	5.44	5.08	5.63
E13	MR-WR	0.7654	0.8764	25	4.50	4.48	5.39
F20	WM-RG	0.7335	0.7335	47	5.25	5.00	5.41
F28	MB-RG	0.6964	0.6224	20	5.33	4.75	5.94
G16	WM-RB*	0.1144	0.1144	37	4.95	4.20	4.30
G23 (1)	MB-RY	0.9505	0.8714	36	5.83	5.82	5.75
K22	MB-RY*	0.1581	0.2540	19	5.58	5.08	4.90
G23 (2)	GM-BY	0.7907	0.7806	20	6.06	5.86	5.86
H05	GM-BR	0.9723	0.8966	58	5.58	4.84	5.44
I13	MR-RY	1.6806	1.3828	40	6.14	5.25	6.02
J16	MB-WY	0.5989	0.8277	38	5.93	5.62	5.86
J19	MR-WY	1.0716	1.1692	72	5.71	5.43	5.15
K24	UNB	0.8596	0.7536	49	5.69	5.52	5.50
L20	MR-RB	0.5720	0.5837	45	5.80	5.36	6.05
O21	MB-RW	0.7049	0.5888	37	6.11	5.54	5.69

Mean base territory area = 0.9159 (S.D. = 0.4888)
Mean adjusted territory area = 0.9107 (S.D. = 0.4809)

KEY * = no female
UNB = unbanded bird

Very little habitat variation in the average canopy, tree and DBH measurements occurred between the warbler areas (Table 3.1).

Nesting outcome

During the 1987-88 breeding season a total of 43 warbler nests were built, 127 eggs laid and 20 chicks fledged, only 10 warbler chicks are thought to have survived for more than a week after fledging along with 4 shining cuckoo chicks. On average, each of 16 female warblers built 2.7 nests (s.d.= 0.77), laid 7.9 eggs (s.d.=3.40) and fledged 1.3 warbler chicks (s.d.= 1.44) during the one season.

Of the 43 warbler nests in the study area, 9 fledged warblers (20.9%), four fledged cuckoo chicks (9.3%), the remaining 30 (69.8%) failed. The main causes of nest failure or loss are set out in Table 3.2

Table 3.2 NEST OUTCOME FOR WARBLERS 1987/88.

	Causes of Nest Failure		Number of Nests	
EGG STAGE	Climatic factors eg. wind damage		7	(16.7%)
	Nest abandonment unknown factors		4	(9.5%)
	Predation	mammal 7} avian 3}	10	(23.8%)
CHICK STAGE	Died in nest natural causes		4	(9.5%)
	Predation	mammal 2} avian 2}	4	(9.5%)
FLEDGED CHICKS		warbler 9} cuckoo 4}	13	(31.0%)
		totals	42	100.00

Predation

Circumstantial evidence suggested that the Australasian harrier (Circus approximans) was the main avian predator of warbler nests in the study area. Harriers were confined to the canopy, while the other suspected avian predator, the Australian magpie (Gymnorhina hypoleuca tibicen), was often found below the canopy. Male warblers were seen attacking the nests of other pairs (H. Cameron and I. McLean, pers comm.), and a shining cuckoo was observed in the study area flying away from a warbler nest carrying an egg (I. McLean, pers comm.). The main mammalian nest predators appeared to be rats, however cats were also present in the study area. Mammalian predators seemed to take nests close to the trunk on more stable branches below the canopy. Bird bones, feathers and colour bands from warblers were found in cat faeces.

For 39 nests for which nest and tree descriptions were complete (Table 3.3), no significant differences were found between the heights of failed nests compared with heights of nests which were not attacked or damaged (anova $F = 1.44$, $p > 0.05$). There was also no significant difference between canopy heights or tree heights for failed nests compared with those not attacked or damaged (anova, $p > 0.05$). However, nests damaged by wind or rain were significantly lower than those not damaged ($F = 8.25$, $p < 0.01$).

Table 3.3 INFLUENCE OF MEAN CANOPY, TREE AND NEST HEIGHTS ON NEST OUTCOME

		mean canopy ht	mean tree ht	mean nest ht
predated (?) nests	n = 14	5.07	4.89	4.37
wind and/or rain damaged	n = 7	4.14	4.18	3.71
not attacked or damaged	n = 18	5.47	5.03	4.64

The breeding success varied between pairs (Table 3.4). One female built four nests, produced 14 eggs and still failed to fledge any chicks. Another female built two nests, mating two different males and fledged a total of 4 chicks. There was no significant difference between territory sizes of successful and unsuccessful nests (Two sample t-test, $p > 0.05$)

Table 3.4 NESTING SUCCESS FOR GREY WARBLERS 1987/88

Terr. code	male bands	female bands	# nests built	# eggs (warbl)	# chicks hatched	# chicks fledged	fledg.surv. (1 week)
C12	YM-RW	unb	4	14	2	0	0
C19	MB-RB	MB-RG	1	0	3	-	-
		unb	3	8	0	cuckoo	(cuckoo)
D15	MB-WR	unb	2	2	0	0	-
D26	M-WG	YM-RG	4	11	2	2*	1
E13	MR-WR	MR-YB	3	10	0	cuckoo	(cuckoo)
F20	WM-RG	**WM-RW**	2	7	3	0	-
F28	MB-RG	GM-BG	3	8	5	3	2?
G16	WM-RB	no female	-	-	-	-	-
G23 (1)	MB-RY	**YM-RY**	1	4	3	3	2
	MB-RY	no female	-	-	-	-	-
G23 (2)	GM-BY	**YM-RY**	1	4	2	1	-
H05	GM-BR	unb	2	8	2	1	1
I13	MR-RY	unb	3	11	3	0	-
J16	MB-WY	MB-WY	2	6	1	1	1
	MR-WY	unb	3	10	2	cuckoo	(cuckoo)
K24	unb	GM-RW	3	8	5	3	1
L20	MR-RB	MR-RG	2	5	3	3	1
		WM-RW	0	0	-	-	-
O21	MB-RW	unb	3	11	3	3 + cuck	(cuckoo)
		totals	42	127	39	20 warbler 4 cuckoo	10 warb 4 cuck

KEY Females that swapped males in **Bold** .
* = 2 chicks found on ground under nest after a strong wind and replaced, would have died if left.

Nest location

Nest locations were concentrated towards the territory boundaries. Twenty four nests were found on the boundary of the territory, 9 within 10 m of the boundary and only 8 over 10 m from an edge (one nest was not found) (Table 3.5).

Table 3.5 NEST SUCCESS IN RELATION TO NEST LOCATION

Position of Nest Site	Fledged Successfully	Unsuccessful	
on boundary (= 0m)	9	15	24
near boundary (<10m)	3	6	9
terr. centre (>10m)	0	8	8
	12	29	totals

Song rates

Song frequency data were obtained for male warblers. Males with the highest song rates were unpaired, with males generally being quieter while in the company of a female (Table 3.6). Once a female left the male to fly back to the nest, the male often sang more, though compared with an unpaired male the song frequency was low. Males sang loudly in response to the song of another male at any time.

Table 3.6 SONG RATES FOR MALE WARBLERS WITH AND WITHOUT FEMALES.

	songs / min.	No. of samples	tot. min.
M with no F	1.723	8	76
M with F at nest or nearby (incl. 3 non singing birds)	0.240	6	50
M with F at nest or nearby (excl. 3 non singing birds)	0.600	3	20

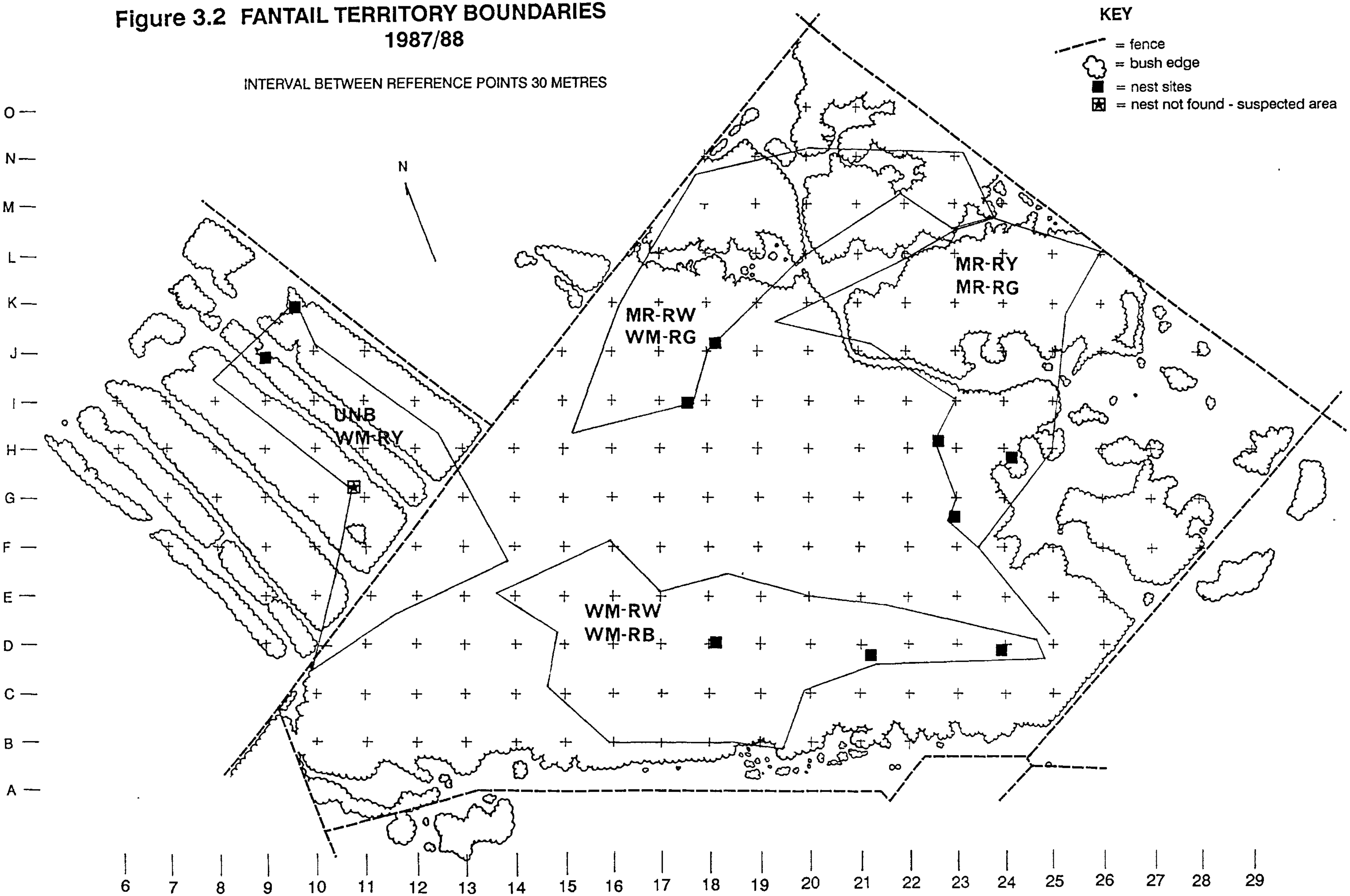
Territory swapping

Two known cases of territory swapping occurred late in the season. In one case a female bird gave up incubating her nest of 3 eggs and "moved in" with a male 150 m away who had lost his female about six weeks

Figure 3.2 FANTAIL TERRITORY BOUNDARIES 1987/88

INTERVAL BETWEEN REFERENCE POINTS 30 METRES

KEY
= fence
= bush edge
= nest sites
= nest not found - suspected area



earlier. One partially built nest was found but was never used in her new area. Her original mate remained in the first territory. In the other case a banded male was ousted from the territory by a new unbanded bird. The new male took over the territorial defense and mated with the female. The displaced male moved to a small area of approximately 900 m^2 some 45 m away. The female in this case succeeded in raising two clutches to fledging age, both by different fathers, without moving territory. The new male seemed to maintain similar territorial boundaries as the previous bird, presumably defined by the neighbouring birds.

FANTAILS

Home range size

Fantail territories were much larger than those of warblers, with four pairs present in the 20 ha study area (Fig. 3.2). Calculated home range sizes represent minimum values ranging in size from 2.1287 to 2.7548 ha of plotted area.

Table 3.7 AREAS, CANOPY AND TREE STUCTURE FOR FANTAIL TERRITORIES

Terr. code	bands		territory area (ha)	plots	canopy ht(m)	ave tree ht(m)	ave tree DBH(cm)
D21	WM-RW	m	2.7548	33	5.04	4.80	5.18
	WM-RB	f					
H24	MR-RY	m	2.2070	25	5.66	5.45	5.43
	MR-RG	f					
J10	unb	m	2.4104	19	5.92	5.00	5.38
	WM-RY	f					
J17	MR-RW	m	2.1287	24	6.00	5.59	5.87
	WM-RG	f					

KEY m = male
f = female

As with the warblers, little habitat variation exists between the four fantail territories.

Nesting outcome

The four pairs of fantails built 13 nests, laid 36 eggs, and fledged a total of 28 chicks. Fantail nesting success was high with only three nests failing to fledge at least one chick (table 3.8).

Table 3.8 NEST OUTCOMES FOR FANTAILS 1987/88.

	Causes of Nest Failure	#	%
EGG STAGE	Climatic factors eg. wind	1	(7.7%)
	Predation (?rat)	1	(7.7%)
CHICK STAGE	Study activities	1	(7.7%)
FLEDGED CHICKS		10	(76.9%)
	totals	13	100.0

The only nest to be eaten in the study area was undamaged, and the culprit was unknown, but probably a rat (Rattus rattus). All chicks died in a nest that was used for a caging experiment, other caged nests were successful (ch.1)

Table 3.9 NESTING SUCCESS FOR FANTAILS 1987/88

Terr. code	bands		# nests built	# eggs	# chicks hatched	# chicks fledged	chick surv (1 week)
D21	WM-RW	m	3	10	7	5	4+
	WM-RB	f					
H24	MR-RY	m	4	15	11	8	?
	MR-RG	f					
J10	unb	m	3	10	8	8	?
	WM-RY	f					
J17	MR-RW	m	3	11	10	7	6
	WM-RG	f					
	totals		13	36	36	28	10+

Nest location

Fantail nest locations were also positioned near territory boundaries. Seven of the 10 nests found were on the boundary edge (Fig 3.2)

DISCUSSION

It can be assumed that the study area supplies whatever requirements are needed for fantails and warblers to live and breed. Fantails and warblers have very different breeding strategies. Fantails demonstrate almost equal parental effort, while warbler females do all the building, laying, and incubating, and are the prime feeders of the chicks. These two species showed very different rates of breeding success. Why are some birds more successful at rearing offspring than others?

Defended territories of both species break down outside the breeding season (Powlesland 1982; Gill, 1980). Pairs from the previous season generally retained the same mate and similar territory location. Since some birds were new to the area, competition determined the final territorial spacing.

Population density

The distribution of fantail and grey warbler territories was dissimilar. Grey warbler territories were contiguous throughout the study area. Very little space was not used by warblers suggesting the warbler population was approaching a maximum for the habitat available. Conversely, fantails appeared to be present in sub-maximal density, with much of the study area apparently little used.

Territory area

The average unadjusted territory size for warblers in the study area was 0.9158 ha. (S.D. = 0.4888). This agrees with Gill's findings of warblers in "habitat 1" (stunted, open kanuka forest similar to our study area) where 0.9150 ha (S.D.= 3130) was the average territory size. Gill suggests that warblers in Kowhai Bush exist at close to a limit set by food availability. According to Schoener (1968), a predatory bird with the mass of a grey warbler (6.4 g, Gill 1980) should have a territory area of the order of 0.2500 ha., whereas warblers have areas nearly four times this size. This could be partly explained by the limited habitat diversity available. Gill found that tall diverse forest at Kowhai bush resulted in territories being half the size of the less diverse areas. Grey warblers (NZ's smallest bird by mass) produce a large egg relative to other passerines. Female warblers lay 93% of their body weight as eggs over 8 days. Up to four clutches were layed by a single female in one season. She therefore requires relatively more food for the volume of eggs produced than most other species.

Using Schoener's (1968) results fantails (7.6g, n=65, Powlesland, 1982) should occupy just over 0.3640 ha.. Areas of 0.3525 and 0.0762 ha., were calculated for two territories in suburban Gisborne (Blackburn, 1965), the larger being in good agreement with Schoener's work. In Kowhai Bush the average area (n=4) was 2.3752 ha, or 6.5 times the predicted area. The implication is that many more fantails could live in this area and the low density could be caused by a number of factors. Food availability may be limiting, although fantail pairs present bred very successfully. A poor breeding season the year before might have resulted in a low recruitment of birds into the area, but further comment is not possible on this point as data are insufficient.

Effectiveness of breeding effort

For every 100 warbler eggs produced only 17.5 chicks could be expected to fledge. In comparison, from the same number of fantail eggs 77 chicks could be expected to fledge. Since all the physical aspects of the study area were the same, as were many of the influences, such as predation, and food availability, the question becomes what causes nests to fail? Behavioural aspects may be the key.

At the begining of the breeding season male warblers are easily identified by their songs which are repeated frequently especially prior to gaining a female. Song appears to fulfil two roles, one is to attract females and the other is in territorial definition (Wilson, 1975). Since song rates decrease significantly with gaining a female, the assumption is that song is more useful to the male in advertising for a female than for territorial defence. Catchpole (1972), noted that reed warblers also decrease their singing rate after gaining a female.

Song must still carry some territorial significance as male warblers are highly aggressive towards taped warbler songs within their territories. This behavior may be better explained by the males 'fear' of having his female sung away from him.

Song also plays a part in territorial definition and nest positioning amongst fantails (McLean, 1980).

Breeding is an expensive activity for any small bird. Typically, the grey warbler female leads the pair in the search for food while the male follows closely, behind and below. The high female investment in breeding is protected by a highly aggresive male. The female generally feeds at a high rate in the canopy while the following male keeps to the more open lower canopy and trunk zones. Obtaining food is probably more important to the female than territorial boundaries, especially if no challenge is met. The female appears to push the home range boundaries to the outer limits while being 'protected' by the male. The more balanced division of labour found in fantail pairs makes for a more even distribution of feeding effort.

Nest location

Both fantail and warbler nests show non random positioning within the territory. One might expect the central area of the territory to be the most economic location for the nest as far as foraging effort is concerned (Krebs et al., 1987). It is also likely to be the most well known part of the territory, therefore better nest sites should be known, and potentially distractive behavior could be more successful against predators. This study and that of McLean (1980) found that fantails nested away from the territory centre. Only 29% of warbler nests were built in the centre of the territory and none of these fledged chicks. All the other warbler nests were within 10m of a territory boundary, most commonly on the very edge. A similar observation was made by May (1947) in willow warblers (Phylloscopus t. trochilus). McLean suggested that nest positioning in fantails was determined by males song post position with the male sharing in nest building. As male grey warblers have nothing to do with nest building or incubation, it is reasonable to suppose that the female is also responsible for choosing the nest site. Why a female warbler should preferentially build in a boundary area is unknown. With a male so intraspecifically aggressive other warblers are actively evicted. When the threat of a predator is present an advantage may be had if other birds can be involved in group mobbing. By nesting closer to the boundary group mobbing of predators might be better achieved without inviting other males into the centre of the territory, or risking not getting the support of the surrounding birds.

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APPENDICES

APPENDIX 1
CAGE MANIPULATIONS AND CONTROLS; 16/11/86 - 05/12/88

CAGING DATES from	to	SPECIES	NEST ID	C	M (see key)	F	c/d	
16/11/86 -	21/11/86	Rflman	D20	2	0	2	10	
21/11/86 -	23/11/86	Grywbl	N18	4	0	4	8	
21/11/86 -	27/11/86	Rflman	C22	3	0	3	18	
24/11/86 -	27/11/86	Grywbl	D21	4	0	4	12	
30/11/86 -	06/12/86	Fntail	K24	3	0	3	18	
08/12/86 -	15/12/86	Rflman	J16	2	0	2	14	
08/12/86 -	12/12/86	Rflman	C16	3	0	3	12	
15/12/86 -	20/12/86	Rflman	F26	2	0	2	10	
17/12/86 -		Grywbl	I23	3	-	-	-	(a)
23/12/86 -	30/12/86	Fntail	bank	3	2	1	18	
23/12/86 -	28/12/86	Grywbl	F13	4	3	1	13	(b)
26/12/86 -	02/01/87	Rflman	D25	3	0	3	21	
28/12/86 -	02/01/87	Rflman	C11	2	0	2	10	
29/12/86 -	05/01/87	Rflman	K20	4	0	4	28	
31/12/86 -	08/01/87	Rflman	H21	3	0	3	24	
03/01/87 -	09/01/87	Rflman	G18	3	0	3	18	
06/01/87 -	13/01/87	Rflman	H12	4	1	3	26	
06/01/87 -	12/01/87	Rflman	K26	1	1	0	7	(c)
09/01/87 -	13/01/87	Fntail	bush	4	4	0	11	
16/01/87 -	23/01/87	Rflman	C13	2	0	2	14	
17/01/87 -	18/01/87	Brncrp	I20	1	1	0	0	
22/01/87 -	24/01/87	Grywbl	H15	3	0	3	6	(d)
********* 1987/88 breeding season **********								
26/09/87 -	02/10/87	Fntail	H24	3	3	0	11	
28/09/87 -	02/10/87	Grywbl	L20	3	0	3	12	
02/10/87	CONTROL	Fntail	J10	3	0	3	-	
04/10/87	CONTROL	Grywbl	G23	4	0	4	-	
02/10/87 -	05/10/87	Fntail	J17	2	0	2	6	
08/10/87 -	12/10/87	Grywbl	D26	2	0	2	8	
16/10/87 -	CONTROL	Grywbl	J16	1	0	1	-	
21/10/87 -	22/10/87	Grywbl	J19	2	2	0	1	(e)
24/10/87	CONTROL	Rflman	L24	2	0	2	-	
26/10/87	CONTROL	Grywbl	F20	2	2	0	-	(f)
26/10/87	CONTROL	Grywbl	H5	1	0	1	-	
01/11/87 -	05/11/87	Rflman	M19	2	0	2	8	
03/11/87	CONTROL	Rflman	I11	2	0	2	-	
05/11/87	CONTROL	Fntail	D24	1	0	1	-	
05/11/87	CONTROL	Fntail	I17	1	0	1	-	(g)
05/11/87	CONTROL	Rflman	C18	3	0	3	-	
09/11/87 -	12/11/87	Grywbl	K26	2	0	2	6	
13/11/87 -	16/11/87	Rflman	D20	1	0	1	3	
13/11/87 -	17/11/87	Grywbl	N20	3	0	3	12	
13/11/87 -	21/11/87	Rflman	H22	4	0	4	32	
14/11/87	CONTROL	Grywbl	I11	1	1	0	-	(h)

14/11/87 -	22/11/87	Rflman	D23	3	0	3	24	
15/11/87	CONTROL	Rflman	C24	1	0	1	-	
16/11/87	CONTROL	Fntail	I17	1	0	1	-	
23/11/87	CONTROL	Fntail	J 9	3	0	3	-	
01/12/87	CONTROL	Fntail	G23	4	0	4	-	
10/12/87 -	16/12/87	Cuckoo	D14	1	0	1	6	
13/12/87 -	16/12/87	Fntail	D18	4	0	4	12	
15/12/87	CONTROL	Cuckoo	bush	1	1	0	-	(i)
19/12/87	CONTROL	Fntail	J18	4	0	4	-	
19/12/87 -	23/12/87	Grywbl	G28	3	0	3	12	
21/12/87	CONTROL	Cuckoo	bank	1	0	1	-	
28/12/87 -	31/12/87	Cuckoo	K18	1	0	1	3	
28/12/87	CONTROL	Grywbl	H21	1	0	1	-	(j)
03/01/88 -	04/01/88	Chaffn	fence	1	0	1	2	(k)
03/01/88	no nest	Fntail	G11	?	?	2	-	(l)
06/01/88	CONTROL	Fntail	G23	4	0	4	-	
06/01/88	no nest	Cuckoo	M23	1	0	1	-	(m)
08/01/88	CONTROL	Cuckoo	fence	1	0	1	-	
12/01/88	CONTROL	Fntail	dump	2	0	2	-	
21/01/88	CONTROL	Cuckoo	D19	1	0	1	-	

*********** 1988/89 breeding season ************

19/10/88	CONTROL	Fntail	G18	3	0	3	-	
07/11/88 -	09/11/88	Rflman	I22	3	0	3	6	
11/11/88	CONTROL	Rflman	K25	3	0	3	-	
19/11/88	CONTROL	Fntail	I09	4	4	0	-	(n)
19/11/88 -	20/11/88	Grywbl	H29	2	0	2	2	
05/12/88 -		Fntail	G18	2	2	0	-	(o)

	C	M	F	c/d
caged total	104	19	85	464
control total	55	8	47	
EXPERIMENTAL TOTAL	159	27	132	
nests not found / no manipulation	6	3	3	
OVERALL TOTAL	165	30	135	

KEY
C = chicks caged
M = chick mortality
F = chicks fledged
c/d = chick/days

(a) = This nest was caged for an hour but released again due to unsettled behavior by the adult birds. By next morning the chicks had been preyed apon.
(b) = Nest attacked by (?) magpie, injuries sustained by 3 chicks.
(c) = Female only feeding.
(d) = Nest attacked by (?) harrier, chicks unharmed.
(e) = chicks died within 24hrs of caging, cause unknown - circumstantial evidence would suggest disease.
(f) = nest attacked by a climbing predator, rat or stoat 3 chicks had been in
the nest just after hatching but only 2 were found after the attack caught up in the tree.

(g) = 2 other nestlings died prior to banding, second nest for this pair.
(h) = 2 nestling died prior to banding, a second clutch; ? disease.
(i) = chick disappeared
from nest adults were later seen preening together, nest looked attacked.
(j) =
this nest had a cuckoo present in the nest which failed to fledge, the warbler survived
(k) = Chaffinch caged for 48hrs, adults not banded.
(l) = Nest not found, two recently fledged chicks found being fed by adults

(m) = Nest not found, cuckoo chick being fed by warblers.
(n) = Chicks suffered predation just prior to fledging.
(o) = Chicks very small, died within 5 hours of caging; adults still feeding fledglings from previous nest.

APPENDIX 2
SUMMARISED INSECT COLLECTION DATA AND COMPLETE INSECT LISTS

	rifleman 16 nests 42 chicks		fantail 5 nests 16>13 chicks		g.warbler 6 nests 15 chicks		s.cuckoo 2 nests 2 chicks	
	##	mg.	##	mg.	##	mg.	##	mg.
ORTHOPTERA (wetas)	13	90.99	1	7.43				
EPHEMEROPTERA (mayflies)			(2)					
HEMIPTERA (plant bugs)	8	6.37	2	1.688	2	1.626		
NEUROPTERA (lacewings)	1	0.56	11(1)	6.204			3	1.69
COLEOPTERA (beetles)	7(2)	11.69	1	2.022	1	1.199	2(2)	2.102
DIPTERA (flies)	24(1)	140.18	6	19.128				
Tipulidae			57(1)	106.57	16(2)	33.14		
Mycetophilidae			265(2)	92.94	3	0.88	4	1.48
Tabanoidea			26(2)	242.75	9	213.84	4	11.94
Asiloidea			26	17.07			14	69.11
Empidoidea			51(6)	71.925	1	0.64	45	220.86
Syrphoidea			76(4)	291.63	21	84.82	32(1)	129.25
Muscidae			84(10)	550.19	13	64.55	2	9.93
Tachinidae			84	947.92	25	280.45	35	392.63
Other diptera small #			14(9)	5.13	(1)			
LEPIDOPTERA (moths)	11	39.36	18	110.16	4(1)	25.48	10	54.32
Tortricoidea	33	96.82	8	23.47	4	11.74	9	26.41
Pyraloidea	283	585.92	73	180.30	57	167.82	82	238.95
Geometroidea	47	564.90	45	571.46	30	360.95	30	391.96
Noctuidae	3	119.85			4	158.60	11	436.15
Other lepid. small #	1	7.04			3	58.23		
Larv./pup. -all types	46	313.22			11	30.38	26	71.81
HYMENOPTERA (wasps)	1	0.38	3(1)	0.84				
ARACHNIDA (spiders)	38(3)	224.27	2	1.861	47	123.328	51	143.274
ISOPODA (slaters)	3	18.02					1	6.01
MIRIAPODS (millipedes)	(2)							
MOLLUSCA (snails)	(1)							
total weighed No.s	519		851		251		361	
total wt (mg.)	2,219.57		3,250.688		1,617.673		2,207.876	
unweighed numbers	10		44		4		3	
total w'd & unw'd	529		895		255		364	
w'd items represent	98.11%		95.08%		98.43%		99.18%	
ave.coll.item wt.	4.2766 mg		3.8198 mg		6.4449 mg		6.1160 mg	

RIFLEMAN 1986-87 Collections from caged nests.

	C11 (2)	C13 (2)	C16 (3)	C22 (3)	D25 (3)	F26 (2)	G18 (3)	H12 (4)	H18 (4)
ORTHOPTERA (wetas/cricket)									
Hemiandrus sp.		2							
Hemidiena femorata					1		1		
Hemidiena sp.								2	1
HEMIPTERA (plant bugs)								1	
Cicadellidae sp.A								1	
sp.B								2	
Miridae sp.A								1	
sp.B								1	
NEUROPTERA (lacewings)									
Micromus tasmanii		1							
COLEOPTERA (beetles)									
Cucujoidea									
Tenebrionidae					1				
Chrysomeloidea									
Chrysomelidae								1	
Eucolaspis brunneus						1		1	
DIPTERA (flies)									
Tipulidae	L	L				L			
Austrolimnophila sp.								L	
Stratiomyidae									
Eulalia ?chloris									1
Therevidae					1		2		1
Dolichopodidae					1				
Hippoboscidae									
?*Ortholfersia macleayi*		1							
LEPIDOPTERA (moths/butterflies)		3	1						
Tortricoidea									
Tortricidae						1	-	19	2
Plantotortrix excessana				1					
?Tortricid larvae			1	1	1				
Tortricid pupae	1		3	10	4	4	2		
Gelechioidea									
?Oecophoridae larvae				3					
Pyraloidea									
Pyralidae									
(Crambinae)									
Scoparia sp.	6		2	1	9	3	2	50	6
Ocorambus flexuosellus					1			1	
Glaucocharis sp.								1	
Geometroidea									
Geometridae	1				1		2	1	
Pseudocoremia lupinata								3	
Pseudocoremia sp.	1	1	1	1	3	1		5	1
Pseudocoremia sp. larvae								1	
Helastia sp. larvae								1	
Noctuoidea									

Noctuidae						
<u>Graphania insignis</u>		2				
ARACHNIDA (spiders)	2		1	1	10	2
Araneidae }						
Theridiidae }						
Lycosidae }						
Thomisidae }						
Stiphidiidae }						
Opilionidae				1		L
MILLIPEDE						
<u>Pseudoprionopeltis</u>					1	

RIFLEMAN continued 1986-88

	86-87			87-88			
	H21 (3)	J16 (2)	K26 (1)	D20 (1)	D23 (3)	H22 (4)	M19 (2)
ORTHOPTERA (wetas/crickets)							
<u>Hemidiena</u> sp.	2	2	1		1		
HEMIPTERA (bugs)							
Miridae	2						
COLEOPTERA (beetles)							
Elateroidea							
Elateridae				1			
Chrysomeloidea							
Chrysomelidae					3		
<u>Eucolaspis brunneus</u>						1	
DIPTERA (flies)	1						
Tipulidae	L	2			L	L	
<u>Leptotarsus dichroithorax</u>	1						
Mycetophilidea							
species #7					1		
Stratiomyidae							
<u>Eulalia chloris</u>	1						
Therevidae	2						
Asilidae	1						
Dolichopodidae	1						
<u>Chrysosoma</u>		1					
Muscoidea							
Muscidae	1						
Tachinidae	3	1			1	1	
LEPIDOPTERA (moths/butterflies)	1	1		2		2	1
Tortricoidea							
Tortricidae	10						
?Tortricid larvae	1						
Tortricid pupae	5	4					
Yponomeutoidea							
?Glyphipterigidae	1						
Gelechioidea							
?Oecophoridae larvae		1					
Pyraloidea							
Pyralidea							
(Crambinae)							
<u>Scoparia</u> sp.	14			3	87	14	
<u>Scoparia steropaea</u>	3				74	6	
<u>Glaucocharis</u> sp.							
Geometroidea							
Geometridae	4	1			4	1	1
<u>Pseudocoremia lupinata</u>		2					
<u>Pseudocoremia</u> sp.	5				1	1	
<u>Helastia</u> sp. larvae	3						
Noctuoidea							
Noctuidae							
<u>Graphania insignis</u>					1		

HYMENOPTERA (wasps/bees/ants)								
Ichneumonoidea								
Brachonidae	1							
ARACHNIDA (spiders)	6	2	1		3	3	5	2
Araneidae								
Theridiidae								
Lycosidae								
Thomisidae								
Stiphidiidae								
Opilionidae	2							
MILLIPEDE								
<u>Icosidesmus</u> sp.							1	
ISOPODA								
slater	2						1	
MOLLUSCA								
Gastropoda					1			

FANTAIL 1986-88

	86-87 main bush (4>3)	86-87 stop bank (3>1)	87-88 D18 (4)	87-88 H24 (3)	87-88 J17 (2)
ORTHOPTERA (wetas / crickets)					
Hemideina sp.	1				
EPHEMEROPTERA (mayflies)	1	1			
HEMIPTERA (plant bugs)					
Cicadellidae	1	1			
NEUROPTERA (lacewings)					
Micromus tasmanii	11				
Drepanacra binocula	1				
COLEOPTERA (beetles)					
Chrysomeloidea					
Chrysomelidae	1				
DIPTERA (flies)			6		
Tipulidae		L	L		
Leptotarsus (*Macromastix*) sp.		1			
Leptotarsus dichroithorax		2	1		
Limonia (*Zelandoglochina*) sp.				30	
Zelandoglochina crassipes				13	11
Culicidae		2			
Chironomidae				10	
Simulidae					1
Anisopodidae					
Sylvicola sp.		1			1
Mycetophilidae		1	12?		
Australosymmerus trivitatus			1		2
species #1				2	
species #2				4	
species #3				1	
species #4				1	
species #5					1
species #6			1	1	
species #8		1	1		2
species #9		1			
species #10	1				
species #12				2	2
species #13				1	
Mycetophila fagi		13	15	2	
Mycetophila marginepunctata				1	
Mycetophila variabilis					1
Macrocera scoparia		1	6		
Macrocera milligani				3	
Nervijuncta sp.		1			
Synapha apicalis				11	9
Anomalomyia sp.			4	3	
Anomalomyia affinis			6	30	63
Anomalomyia guttata				6	6

Parvicellula sp. nr *gracilis*		1		31	17
Platyura sp.		1	1	6	2
Platyura brevis				1	
Tabanoidea					
Tabanidae	1	6	1		
Stratiomyidae		1	1		
Eulalia sp.		7			
Eulalia chloris	9	4	3		
Eulalia dorsalis	1				
Asiloidea					
Therevidae			11		
Anabarrhynchus sp.	8	1	2		
Asilidae		1	1		
Bombyliidae					
Tillyardomyia gracilis			2		
Empidoidea					
Empididae	1				
Scelolabes fulvescens	1				
Dolichopodidae	1		7	1	
Chrysosoma sp.	8	22	8	2	2
Chrysosoma dichaetum		3	2		
Phoroidea					
Sciadoceridae					
Sciodocera rufomaculata		1			
Syrphoidea					
Syrphidae					
Melangyna sp.	2			1	
Melangyna (Austrosyrphus) sp.			3		1
Melangyna (A.) novaezealandiae	32	5	16	10	2
Melanostoma sp.			3		
Melanostoma fasciatum	2			1	
Helophilus hochstetteri				1	
Lepidomyia decessum	1				
Sciomyzoidea					
Lauxaniidae	1				
Heleomyzoidea					
Heleomyzidae					
Allophylopsis scutulata				1	1
(?)Pallopteridae					
Neomaorina lamellata				1	
Drosophiloidea					
Ephydridae					
Scaptomyza fuscitarsis					1
Muscoidea					
Muscidae	29	6	3	18	16
Calliphoridae	4		2	4	
Calliphora quadrimaculata	9	1		2	
Sarcophagidae					
Hybopygia varia	1				
Tachinidae	20	31	13	12	4
Pales sp.	2				
Evibrissia huttoni	2				
LEPIDOPTERA (moths/butterflies)	1	8	5	4	

Tortricoidea						
Tortricidae	8					
Gelechioidea						
Oecophoridae						
Phaeosaces apocrypta		1				
Pyraloidea						
Pyralidea						
(Crambinae)						
Scoparia sp.	12	18		19	3	
Ocorambus flexuosellus	2	5				
Scoparia steropaea	2	2		4	6	
Geometroidea						
Geometridae						
Pseudocoremia lupinata	1	3		1		
Pseudocoremia sp.	25	2		13		
HYMENOPTERA (wasps/bees/ants)						
Ichneumonoidea						
Ichneumonidae						
Aucklandella					1	
Braconidae						1
Metoreus					1	
ARACHNIDA (spiders)						
Araneidae						2

GREYWARBLER 1987-88

	{ greywarbler					chicks }	{ cuckoo	}
	D26	G28	J19	K26	L20	N20	D14	K18
	(2)	(3)	(2)	(2)	(3)	(3)	(1)	(1)
HEMIPTERA (plant bugs)								
Cicadellidae	1							
Miridae		1						
NEUROPTERA (lacewings)								
Micromus tasmanii							3	
COLEOPTERA (beetles)								
Cucujoidea								
Coccinellidae							1	
Chrysomelidae								
Eucolaspis sp.						1		
Eucolaspis sp. larvae							2	
Eucolaspis brunneus							1	
DIPTERA (flies)							2?	
Tipulidae	1					1		
Limonia (Zelandoglochina)					15			
Zelandoglochina crassipes					1			
Anisopodidae								
Silvicola sp.		1						
Mycetophilidae								
species #12							1	
Anomalomyia sp.								1
Anomalomyia affinis					2		1	1
Parvicellula sp. nr. *gracilis*						1		
Tabanoidea								
Tabanidae						9		
Stratiomyidae								
Eulalia chloris							3	
Acroceridae								
Ogcodes sp.								1
Asiliodea								
Therevidae							1	
Anabarhynchus sp.							11	
Asilidae							2	
Empidoidea								
Dolichopodidae							44	
Chrysosoma sp.		1					1	
Syrphoidea								
Pipunculidae							1	
Syrphidae								
Melangyna (A.) novaezealandiae		11				10	31	1
Muscoidea								
Muscidea		5			1	7	1	1
Tachinidae	1	1		1	2	20	35	
LEPIDOPTERA (moths/butterflies)				2	1	1	10	
Hepialoidea								
Hepialidae								
Wiseana ?copularis	1							
Tortricoidea								

Tortricidae		1				3	7	2
?Tortricid larvae		3				8	24	2
Yponomeutoidea								
?Glyphipterigidae		1						
Gelechioidea								
Oecophoridae								
Heliostibes illiata		1						
Pyraloidea								
Pyralidea								
(Crambinae)								
Scoparia sp.	4	22			1	20	48	1
Orocrambus flexuosellus				2		8	17	2
Scoparia steropaea							12	2
Geometroidea								
Geometridae	5	4					9	4
Pseudocoremia lupinata		3					1	
Pseudocoremia sp.		2				3	12	1
Pseudocoremia sp. larvae		1			1	9	2	
Asaphodes sp. larvae		2						
Helastia sp. larvae							1	
Noctuoidea								
Noctuidae					3	1	3	
Graphania insignis							8	
ARACHNIDA (spiders)	10	6	1	2	6	22	44	7
Araneidae								
Theridiidae	(grey warblers only had Araneidae,						(all types	
Thomisidae	Theridiidae and Thomisidae)						represented)	
Lycosidae								
Stiphidiidea								
ISOPODA (slaters)								1

APPENDIX 3
INSECT DRY WEIGHTS (CAHN 21 ELECTROBALANCE)

Dry weights measured after drying 15 hours at 60^{o} C using a Cahn 21 electrobalance

RIFLEMAN 1986-87

ORTHOPTERA (wetas/cricket)		mg.
Hemiandrus sp.		4.653
Hemidiena femorata		7.426
HEMIPTERA (plant bugs)		0.7075*
Cicadellidae		0.844
Miridae		0.782
NEUROPTERA (lacewings)		
Micromus tasmanii		0.564
COLEOPTERA (beetles)	(2)	
Eucolaspis ?brunneus		1.199
Chrysomelidae		2.022
DIPTERA (flies)	(1)	5.841*
Leptotarsus dichroithorax		3.304
Mycetophilidea		0.384*
Eulalia ?chloris		3.279
Therevidae		5.215
Asilidae		3.267
Dolichopodidae		5.005
Chrysosoma		0.640
Muscidae		4.965
Tachinidae		11.218
LEPIDOPTERA (moths)		3.578
Tortricidae		2.934
?Tortricid larvae		2.762
Tortricid pupae		6.801
?Glyphipterigidae		7.040
?Oecophoridae larvae		12.937
Scoparia sp.		2.403
Ocorambus flexuosellus		5.488
Glaucocharis sp.		1.209
Geometridae		14.045
Pseudocoremia lupinata		5.971
Pseudocoremia sp.		13.54
Pseudocoremia sp. larvae		11.936
Helastia sp. larvae		3.513
Noctuidae		
Graphnia insignis		39.95
HYMENOPTERA (wasps)		
Brachonidae		0.378
ARACHNIDA (spiders)	(3)	5.47

MIRRIAPOD (millipedes)	(2)	
ISOPODA (slaters)		6.006
MOLLUSCA (snails)	(1)	

FANTAIL 1986-88

ORTHOPTERA (wetas)		
Hemidiena sp.		7.426
EPHEMEROPTERA (mayflies)	(2)	
HEMIPTERA (plant bugs)		
Cicadellidae		0.844
NEUROPTERA (lacewings)	(1)	
Micromus tasmanii		0.564
COLEOPTERA (beetles)		
Chrysomelidae		2.022
DIPTERA (flies)	(41)	3.188
Leptotarsus dichroithorax		3.304
Limonia (_Zelandoglochina_) sp.		2.117
Zelandoglochina crassipes		1.381
Chironomidae		0.062
Simulidae		0.539
Mycetophilidae		0.384
Mycetophila fagi		0.356
Mycetophila marginepunctata		0.435
Macrocera scoparia		0.554
Macrocera milligani		0.333
(?) _Australosymmerus trivitatus_		0.853
(?) _Synapha apicalis_		0.142
Anomalomyia sp.		0.489
Anomalomyia affinis		0.303
Anomalomyia guttata		0.353
Parvicellula sp. nr _gracilis_		0.277
Platyura sp.		1.137
Platyura brevis		0.500
Tabanidae		23.76
Stratiomyidae		0.105
Eulalia chloris		3.279
Therevidae		5.215
Asilidae		3.267
Tillyardomnia gracilis		5.266
Dolichopodidae		5.005
Chrysosoma sp.		0.640
Melangyna novaeseelandii		4.039
Melanostoma sp.		1.312
Melanostoma fasciatum		1.921
Lepidomyia decessum		3.237
Allophylopsis scutulata		0.893
(?) _Neomaorina lamellata_		0.442
Muscidae		4.965

Calliphora quadrimaculata	16.059
Tachinidae	11.218
Pales sp.	21.04
Evibrissia huttoni	4.202
LEpIdOPTeRa (moths)	6.12
Tortricidae	2.934
Phaeosaces apocrypta	1.745
scoparia sp.	2.403
Ocorambus flexuosellus?	5.488
Scoparia steropaea?	1.209
Pseudocoremia lupinata	5.971
?*pseudocoremia* sp.	13.54
HYMENOPTERA (wasps/bees/ants)	(1)
Aucklandella	0.463
Metoreus	0.378
ARACHNIDA (spiders)	0.93

	GREYWARBLER	SHINING CUCKOO	1987-88
HEMIPTERA (plant bugs)			
Cicadellidae	0.844		
Miridae	0.782		
NEUROPTERA (lacewings)			
Micromus tasmanii	0.564		
COLEOPTERA (beetles)			(2)
Eucolaspis sp.	1.199		
Eucolaspis sp. larvae	1.051		
DIPTERA (flies) (3)			(1)
Limonia (Zelandoglochina)	2.117		
Zelandoglochina crassipes	1.381		
Mycetophilidae	0.384		
Anomalomyia sp.	0.489		
Anomalomyia affinis	0.303		
Parvicellula sp.nr. *gracilis*	0.277		
Tabanidae	23.76		
Eulalia chloris	3.279		
Octnodies sp.	2.098		
Therevidae *Annabarhynchus*	5.215		
Asilidae	3.267		
Dolichopodidae	5.005		
Chrysomyia sp.	0.640		
Melangyna novaeseelandiae	4.039		
Muscidea	4.965		
Tachinidae	11.218		
LEPIDOPTERA (moths) (1) GW 6.37* SC 5.432*			
Wiseana ?copularis	51.19		
Tortricidae	2.934		

?Tortricid larvae	2.762
?Glyphipterigidae	7.040
Scoparia sp.	2.403
Ocorambus flexuosellus	5.488
Scoparia steropaea	1.209
Geometridae	14.045
Pseudocoremia lupinata	5.971
Pseudocoremia sp.	13.54
Pseudocoremia sp. larvae	11.936
Asaphodes sp. larvae	8.817
Helastia sp. larvae	3.513
Graphnia insignis	39.65
ARACHNIDA (spiders)	GW 2.624* SC 2.809*
ISOPODA (slaters)	6.006

APPENDIX 4
BREEDING INITIATION DATES FOR RIFLEMAN, GREYWARBLER, FANTAIL AND SHINING CUCKOO

The 1986/87 season was in general later than the following season. A cool preceeding winter probably contributed to this. 1987/88 breeding season duration appeared to be within the normal range for rifleman and shining cuckoo. The first species to begin breeding were the grey warbler followed closely by the fantail. Both species were several weeks earlier than usual and probably reflected the mild winter that year.

BREEDING INITIATION DATES FOR KOWHAI BUSH STUDY AREA 1986-88.

species (N^{o}. pairs)	1st clutch first egg	first chick hatched	2nd clutch first egg	last egg layed	last chick hatched
RIFLEMAN					
1986/87 ( )	22/9/86	18/10/86	9/11/86	26/11/86	16/12/86
1987/88 (17)	13/9/87	10/10/87	8/11/87	15/11/87	28/10/87
Sherley (198?)	8-15/9	1-7/10	1-7/11	8-15/12	1-7/1
GREY WARBLER					
1986/87 (14)	19/9/86	14/10/86	15/11/86	3/1/87	19/1/87
1987/88 (17)	26/8/87	16/9/87	25/10/87	22/12/87	19/12/87
Gill et al (1983)	8/9		23/10	1-7/12	17-23/12
SHINING CUCKOO					
1986/87 (1^{o}*)	?	?	-------	3/2/87	15/2/87
1987/88 (1^{o}*)	30/11/87	12/12/87	-------	26/12/87	6/1/88
Gill (1982)	14/10/78	29/10	-------	1/1/24	17/1
FANTAIL					
1986/87 (?5)	15/10/86@	1/11/86@	-?-	16/12/86	2/1/87
1987/88 (4)	28/8/87	17/9/87	mid Oct.	16/12/87	2/1/88
Powlesland (1982)	10/9/76	24/9	Oct-Nov.	Jan.	20/1/79

Notes;

1) Where only the begining or end of a breeding phase was known, other dates were extrapolated if field data was unknown. Nest that failed (including predation) were not used for extrapolations.

2) * = Gills calculation that one cuckoo female could cover 20 ha., study area 20.25 ha.- a minimum of one female cuckoo (Gill, 1980).

3) @ = These nests possibly second clutch nests.